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DIRECT LIQUEFACTION PROOF-OF-CONCEPT PROGRAM
Hydrocarbon Technologies, Inc., Lawrenceville, N.J.

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V.R. Pradhan
T.L.K. Lee
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FINAL

Topical Report
Bench Run 02 (227-91)

Work Performed Under Contract No. AC22-92PC92148

For

U.S. Department of Energy
Pittsburgh Energy Technology Center

By

Hydrocarbon Technologies Inc., Lawrenceville, NJ,

September 1996

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report presents the results of Bench Run PB-02, conducted under the DOE Proof of Concept - Bench Option Program in direct coal liquefaction at Hydrocarbon Technologies, Inc. in Lawrenceville, New Jersey. Bench Run PB-02 was the second of the nine runs planned in the POC Bench Option Contract between the U.S. DOE and Hydrocarbon Technologies, Inc. The primary goal of this bench run was to evaluate the hybrid catalyst system, consisting of a dispersed slurry catalyst in one of the hydroconversion reactors and conventional supported extrudate catalyst in the other hydroconversion reactor, in a high-low two-stage temperature sequence, similar to the one operated at Wilsonville. This hybrid mode of operation with the high-low temperature sequence was studied during direct liquefaction of coal and in coprocessing of coal with Hondo resid and/or waste plastics under high space velocity operating conditions. Another important objective of Bench Run PB-02 was to investigate the novel "interstage internal recycle" of the second stage reactor slurry back to the first stage reactor. Other features of PB-02 included the use of an interstage separator and an in-line fixed bed hydrotreater.

In general, it was found during Bench Run PB-02 that the 'hybrid type' catalyst system was not effective for obtaining high levels of process performance as the 'all dispersed' catalyst system, tested earlier, especially at high coal space velocities. The interstage internal recycle of second stage reactor slurry to the first stage reactor feed line was found to improve cracking of liquefaction products, as exemplified by the increased naphtha products. The addition of small amounts of mixed plastics, representing a typical MSW waste plastic material, was found to improve the hydrogen utilization in both coal conversion and heavy oil hydrocracking reactions, i.e., plastics resulted in improving the overall distillate yield while at the same time reducing the light gas make and chemical hydrogen consumption.

EXECUTIVE SUMMARY

Bench Run PB-02 was the second of the nine runs planned in the POC Bench Option Contract between the U.S. DOE and Hydrocarbon Technologies, Inc. The primary goal of this run was to evaluate the hybrid catalyst system (dispersed slurry and supported extrudate catalysts) for direct coal liquefaction and for coprocessing of subbituminous Black Thunder mine coal with waste organics, such as waste plastics, and heavy resid. Bench Run PB-02 employed iron and molybdenum-based dispersed slurry catalysts in the first stage back-mixed reactor and supported NiMo/Alumina catalyst (Akzo AO-60) in an ebullated second stage reactor with an interstage high-pressure product separator and an in-line fixed bed hydrotreater.

The overall run plan consisted of eleven operating conditions which included coal-only feed, resid- only feed, coal/resid combined feed, resid/plastics combined feed, and coal/resid/plastics combined feed. The flexibility of the unit to vary operating conditions, such as space velocities, reactor temperatures, and catalyst types and loadings, was demonstrated for five different feed mixtures over a span of 43 days. Among the significant objectives of this bench run were the investigation of "internal recycle" (interstage recycle) of reactor K-2 product to the first stage reactor K-1 without pressure let-down; to examine the beneficial effects of adding small amounts of waste plastics, and to study the effects of a hybrid catalyst system on the overall process performance. During the entire run, 50 ppm of molybdenum from Molyvan-A and 5000 ppm iron from HTI's iron catalyst were introduced with the feed to reactor K-1. Following are the highlights of bench-run PB-02:

- During the 'coal-only' feed conditions, coal conversions (based upon quinoline solubility) varied between 90 and 94 W% maf; 524°C+ resid conversions varied between 81 and 88 W% maf, while the C_4-524°C distillate yield changed from 57 to 64 W% maf. Hydrogen consumption was about 6 % (maf), and C_1-C_3 light gas yield varied between 8.5 and 12.5 W% (dry).

- The internal recycle of reactor K-2 product material to reactor K-1 during Condition 4 of the coal-only feed operation was found to improve the cracking of liquefaction products as it increased the selectivity to the lightest boiling naphtha fraction. It was interesting to find that no negative kinetic impact of practising such interstage internal recycle was observed despite the fact that it led to an increased backmixing in the reaction system, which is known to be kinetically inferior to the plug-flow behavior.

- Conditions 6, 7, and 11 were conducted with heavy oil (Hondo resid) alone at comparable process severities. Conversion, based on quinoline solubility, was over 99 W%, indicating that minimal coke was formed during the heavy oil conversion. The light gas yield was about 5 W%, while resid conversion was over 75 W% and distillate yield was as high as 72 W% (all maf). All this was observed at a low hydrogen consumption of 1.7 W% (dry).

- The presence of a small amount of coal (5 W%) with Hondo resid during Condition 7 (Period 30), marginally improved heavy oil hydrocracking, compared to Period 26 from Condition 6.

- The presence of small amounts of waste plastics (10 W%), with either coal or heavy resid, had a positive impact on process performance. The addition of waste plastics in small amounts to coal during Condition 9 (Period 38) reduced the light hydrocarbon gas yield from about 9-12 W% to 5.5 W% dry basis; chemical hydrogen consumption decreased significantly, while the distillate yield and residuum conversion decreased, as expected due to the deactivation of the second stage catalyst. The addition of waste plastics in small amounts had a similar effect on heavy oil hydrocracking.

- Hydrotreated second stage separator overheads (SOH) represent the net light distillate products from the process. The quality of these distillates was excellent, starting with the 'coal-only' feed conditions: high API gravities (35-42°), low heteroatom contents (less than 60 ppm nitrogen and sulfur), and high hydrogen contents (H/C ratios above 1.8). The quality of SOH oil improved very significantly in the remaining Conditions that fed various combinations of Hondo resid, coal, and waste plastics. During coprocessing conditions, API gravities increased to about 48-50° , while heteroatom contents decreased to below 30 ppm for sulfur and below 1 ppm for nitrogen. The H/C ratio increased to 1.9-2.0. The weight percent of the lightest naphtha fraction also increased to over 50 W% during coprocessing conditions.

- Economic assessment of PB-02 results shows a slight advantage of using an all dispersed catalyst system with low/high staging, as used in PB-01, over the hybrid system with high/low temperature staging used in PB-02.

BACKGROUND, OBJECTIVE, AND SCOPE OF WORK

The POC Bench Option Project (PB-Series) is geared to evaluate different novel processing concepts in catalytic coal liquefaction and coprocessing of organic wastes, such as plastics, heavy resids, waste oils, and ligno-cellulose wastes, with coal. The long-term performance data from bench-scale operations (30 kg/day) will be used to complement the larger scale process demonstration "Proof-of-Concept" studies for the U.S. DOE. The new ideas being explored in this program include using novel dispersed slurry catalysts, combinations of dispersed and supported catalysts (hybrid mode), and coprocessing of coal with waste plastics, low quality resids, waste oils, and ligno-cellulosic wastes. Because the POC Bench Option Program followed a recently completed Catalytic Multi-Stage Liquefaction (CMSL) Project, one of the primary objectives of the second bench run, PB-02, was to investigate process performance in direct liquefaction and coprocessing modes and also in heavy oil hydrocracking mode of a hybrid system of catalysts (dispersed slurry catalyst in reactor stage K-1 and supported extrudate catalyst in stage K-2). The test would allow direct comparison to PB-01 results that employed only slurry catalysts in both stages. A subbituminous Black Thunder mine coal was used with a California vacuum resid and waste plastics from a northern New Jersey recovery facility.

The second POC Bench Option run, designated as PB-02, was carried out for 43 operating days, spanning eleven process conditions, to evaluate the effects of a hybrid catalyst system, i.e., dispersed catalyst only in reactor stage K-1 and extrudate NiMo/alumina supported catalyst in reactor stage K-2. The run studied the direct liquefaction of a subbituminous Wyoming Black Thunder mine coal, upgrading of a Hondo vacuum resid, coal-oil, and coal-waste plastics coprocessing with the following primary objectives:

- To examine hybrid operation with dispersed and supported catalysts, as conducted at Wilsonville, using a high-low, two-stage temperature sequence, with interstage product separation, and in-line distillate hydrotreating.

- To examine the beneficial effects of waste plastics on direct coal liquefaction and heavy oil hydrocracking reactions.

- To determine the effect of added dispersed catalysts, especially molybdenum, in improving the deactivation behavior of the second stage supported extrudate catalyst.

- To determine the impact of an "internal recycle" of reactor K-2 slurry to K-1 without reducing its pressure and temperature.

- To determine if small amounts of coal can act as a "scavenger" in heavy oil hydrocracking reactions.

The detailed run plan for PB-02 is shown in *Table* 1. As mentioned earlier, an in-line hydrotreater was used during this run. The separator overheads from both the first and second stages were sent through the hydrotreater along with the atmospheric still overheads and process knock-outs.

SYSTEM CONFIGURATION

Bench Run PB-02 involved two equal volume back-mixed reactors with internal re-circulation. The first stage reactor, K-1, used only dispersed catalyst, added to feed, while the second stage reactor, K-2, employed an ebullated bed of Akzo AO-60 NiMo/alumina catalyst. Other key features of this run include a novel 'internal recycle' (interstage recycle) concept, wherein the reactor K-2 slurry (after vapor/liquid separation) was sent back to reactor K-1 without reducing the pressure or temperature of the stream. Coprocessing of vacuum resids and waste plastics with coal, staged fresh dispersed catalyst addition, interstage separation and on-line hydrotreating of light products from both stages were other features of the run.

The flow-diagram of the bench unit assembled for run PB-02 is shown in *Figure 1*. Unit 227 and part of Unit 238 were used in this run. Coal, resid, and waste plastics were introduced through the feed system of Unit 227. Light products and gases from the first stage were removed from the hot separator of Unit 238. After separating out the process water, the oil fraction was repressurized and combined with ASOH and the second stage hot separator (O-1) overheads for feeding to the in-line hydrotreater. Slurry product was removed from the bottom of the second stage hot separator (Unit 227). An off-line pressure filtration unit was used to recover a solids-free liquid (recycle solvent) from the slurry product. Two independent gas feed and discharge systems were required to handle gas with the interstage separation configuration. The first stage off-gas was vented through the cold separator of Unit 238.

FEED MATERIALS - COAL, HONDO RESID AND WASTE PLASTICS

Wyoming Black Thunder mine coal, the same coal that was used in PDU 260-005 operations, was used for Bench Run PB-02 (227-90). The analyses of coal, Hondo resid, and waste plastics are shown in *Tables 2* and *3*.

START-UP AND MAKE-UP OIL

A mixture of coal-derived distillate and petroleum-derived, hydrotreated, FCC decant oil, L-814, was employed as start-up and make-up oil; the analysis is shown in *Table 4*.

CATALYSTS

Hydrotreater:	Criterion C-411 Trilobe (HTI-6135)
K-1:	Fresh Molyvan-A, slurried with unit feed, at 50 ppm on dry coal, and Fresh HTI iron catalyst, slurried with unit feed, at 5000 ppm iron on dry feed coal
K-2:	Supported NiMo/alumina, Akzo AO-60 1/16" extrudates (presulfided)

INTERSTAGE (Reactor K-1 Effluent) SLURRY SAMPLES

Seven interstage (reactor K-1 effluent) slurry samples, one for each condition, were planned.Only one sample, representing the Condition 1, was collected before the interstage sampling system plugged.

SAMPLES FOR CONSOL, INC.

Process stream samples, collected during work-up periods for Consol, Inc., are listed in *Table 5*.

SUMMARY OF OPERATIONS

Unit Modification and Configuration

For Run 91, Unit227 was set up to process subbituminous coal, petroleum resid, and waste plastics using two 2000-cc reactors with interstage separation. The first stage (K-1) contained no supported catalyst, using slurry catalysts mixed with the feed. The second stage (K-2) was an ebullated bed reactor, containing Akzo AO-60 NiMo catalyst (HTI-6135). Recycle pump with hot check valves provided recycle flow from K-2 to K-1 for Conditions 3 through 6. This run also used an in-line hydrotreater and a reactor preheater coil.

Figure 1 is a simplified flow diagram of Unit 227 for this run. 6-hour blends of feed slurry were prepared in a separate mix tank (P-7), transferred to the feed tank (P-2), and pumped to the backmixed K-1 reactor via a short-residence-time (approximately 5 minutes) preheater coil. The light products and gases in the effluent from K-1 were removed by an interstage separator (O-1A). The light liquid products were separated from the non-condensibles in the interstage cold separator (O-2A). The O-1A bottoms were sent to the second stage ebullated bed reactor (K-2). Part of the internal recycle for K-2 was diverted as recycle to K-1 for Conditions 3 through 6. The products from K-2 were separated using a hot separator (O-1). The O-1 bottoms were let depressurized and sent to an atmospheric still (CAS). Overheads from O-1 flowed through the in-line hydrotreater (K-3) and then a cold separator (O-2) along with the repressurized oil portions of O-2, O-2A, and CAS overhead. The bottoms from CAS were sent to a pressure filter. Filtered liquids combined with similar liquids extracted by toluene from the filter cake provided the liquid for slurrying the coal feed for Conditions 1 through 3 and 9, during which the fresh feed did not include Hondo resid.

Run Conditions

Run 227-91 included eleven different conditions. The primary variables were the reactor temperatures and feed composition.

Startup

Startup consisted of establishing the proper flows of oil and gases, ebullating and presulfiding the supported catalyst in K-2, setting vessel temperatures, and increasing the reactor temperatures to 413 °C. Filtered L-814, heavy gas oil from PDU operations, was used as a startup oil for this run. The recycle material generated during the reactor heat-up period was used to slurry the coal at the beginning of Period 1. Some issues that arose and were resolved during the startup were solids in the charge pump checks, problems with the K-2-to-K-1 recycle pump, a hydrogen flow restriction, hot separator level control problems, and a shorted K-2 heating rod.

Condition 1 (Periods 1 through 7)

Period 1 started with the introduction of coal feed at 0400 hours on November 28, 1995. (Each 24 hour period started and ended at 0400 hours.) The feed rate and reactor temperatures were gradually increased, reaching full coal rate at 1600 hours of Period 1 and Condition 1 temperatures of 446 °C (K-1) and 418 °C (K-2) at 0600 hours of Period 2. However, the K-2 temperature was increased to 429 °C at the start of Period 4.

There were numerous charge pump outages during the first eight hours of coal feed, including one hour when both pumps were off line and buffer flow was increased to the reactors. Slurry feed problems were overcome, but the hot separator (O-1) level became erratic, flooding overhead and overdumping. In Period 5 the interstage separator (O-1A) outlet became blocked. It was drained manually, and the unit was put on wash at 400 °C for 24 hours. At 1015 hours of Period 6, coal feed was restarted, and reactor temperatures were increased, reaching Condition 1 specifications at 1200 hours of Period 7. Except for cleaning the feed pump checks twice, operations during restart and the remainder of Condition 1 went smoothly.

A 548 g first stage sample was obtained, but flow through the sample system could not be restored for the Condition 2 sample.

Condition 2 (Periods 8 through 10)

In Condition 2 the feed rates of coal and filter liquid (PFL) were increased from 1465 to 1832 g/h, and the feed rates of tert-nonylpolysulfide (TNPS) and iron and Molyvan-A catalysts were similarly increased about 25 %. The K-1 temperature was increased to 452 °C. The feed rate changes were complete by 1000 hours (Period 8), and the temperature change by 0400 hours (Period 9).

During Condition 2 there were several problems with the atmospheric still (CAS). It had to be manually drained when the control valve would not empty it, and another restriction caused it to flood into the overheads. The CAS circulating pump developed a bad leak and was off line for two hours for repacking. In Period 9 the O-1A control valve could not maintain a steady level because it was leaking through with the 150 psi pressure difference between K-1 and K-2. Lowering the pressure difference to 60 psi improved the level control.

Condition 3 (Periods 11 through 14)

In Condition 3 the recycle of slurry from K-2 to K-1 was started. The quantity of this recycle was maintained at 10 to 20 % of the K-2 ebullation flow. This transition went smoothly. Also, the feed rate of H_2S was increased from 40 to 50 g/h. During the transition Period 11, 200 g/h of a 0.1 N acetic acid solution was charged to O-1 and O-1A for two hours to dissolve any salt deposits.

There were some problems handling the slurry feed as its viscosity increased from 3800 to as high as 7000 cps during Condition 3, even as the feed circulation temperature was increased from 120 to 182 °C. Twice, there was difficulty transferring the feed blend from the slurry preparation tank (P-7) to the slurry feed tank (P-2). The spare charge pump had to be put on line several times, and there were feed disruptions totalling 70 minutes when neither pump was operating. Cleaning the pump checks was the usual solution. Because the pressure filtration times increased to longer than four hours, the CAS was shutdown to provide lighter bottoms material for filtering. When insufficient PFL was available to make the feed blend, unfiltered separator bottoms were used instead. The CAS remained off line for the remainder of the run.

Condition 4 (Periods 15 through 18)

In Condition 4 Hondo resid feed was started at a 1:1 ratio with the coal. The PFL recycle was decreased to 312 g/h, and the TNPS feed was discontinued. The slurry feed rate and composition changes were complete at 2200 hours of Period 15.

The feed to the unit became steady during Condition 4. However, mechanical repairs were made on the K-2-to-K-1 recycle buffer pump, the hydrotreater feed pump, the wash oil circulating pump, and the P-7 circulating pump. Twice, the K-1 right-side hot check flow decreased, as indicated by 17 and 5 °C check-temperature drops, but flushing with the buffer pump developed excessive pressure. However, the restriction near the ebullating pump broke, and the temperatures recovered. A heat lamp was placed on the line.

Condition 5 (Periods 19 through 22)

In Condition 5 only Hondo resid and PFL were charged to the feed tank. The transition to the new feed was completed at 2200 hours of Period 19.

There were no feeding problems during Condition 5, but the less viscous products made it difficult for the O-1 and O-1A separators to maintain a level. The K-1 back pressure was lowered to decrease the pressure difference across O-1A to 20 psi.

In Period 22 the pressure drop across K-2 increased to greater than 50 psi. The two K-2 ebullating pump strokes were lowered to 30% and 30%, but the high pressure drop indication remained. Over the next twelve hours, the strokes were increased back to 85% and 85%, at which time the expanded bed was again visible. It was discovered during Condition 6 that this indicated high K-2 pressure drop was actually a restriction in the gas feed line to K-2 and not in the reactor.

Condition 6 (Periods 23 through 26)

In Condition 6 the K-1 reactor temperature was decreased from 845 to 835 °F, and the K-2 reactor temperature was increased from 429 to 438 °C. This change was completed by 1200 hours and was followed by a 400 g acid wash of O-1 and O-1A.

The high pressure drop in the gas feed line to K-2, first experienced in Condition 5, disappeared, but it occasionally reoccurred during the remainder of the run.

The K-1 right-side hot check again had diminished flow. Additional PFL was added through the buffer pump, and a new diaphragm was installed on the ebullating pump. Also, the K-2-to-K-1 recycle buffer pump checks plugged and were replaced.

Feed to the unit was steady, but there was some downstream disruption when reopening the O-1 bottoms block valve, which had been shut to maintain the level.

Condition 7 (Periods 27 through 30)

In Condition 7 the recycle from K-2 to K-1 was terminated. Coal feed was reintroduced at 112 g/h, and the Hondo resid feed rate was decreased by the same amount. The transition went smoothly and was completed by 1000 hours.

Operations during Condition 7 were very smooth. The only difficulty was controlling the levels in the O-1A and O-1 separators at the end of the condition. Relatively low flow rates and viscosities necessitated a low (8 to 10 psi) pressure drop between K-1 and K-2 to minimize the amount of liquid leaking through the closed control valve.

Condition 8 (Periods 31 through 34)

In Condition 8 the coal feed rate was increased to 916 g/h, and the Hondo resid feed rate was decreased to 916 gm/hr. This change was completed by 2200 hours of Period 31.

Operations during Condition 8 were very smooth. However, the outlet of the off-line pressure filter did plug in Period 32, causing loss of PFL.

Condition 9 (Periods 35 through 38)

In Condition 9 the coal feed rate was increased to 1649 g/h, the Hondo resid feed was eliminated, and mixed waste plastic (L-858) feed was started at 183 g/h. The PFL recycle was increased to 1832 g/h. This change was completed by 1000 hours of Period 36, with the plastics introduction occurring during the last 12 hours of the transition. There was a 400 g acid wash of O-1 and O-1A during Period 35.

The plastics-containing feed to the unit was without interruption for the first 18 hours, but then charge pump problems began. The pump checks frequently became plugged with solids. When necessary, L-814 wash oil was either charged to the pumps to help clear them, added to the feed to make it thinner, or charged to the reactors to provide oil when both charge pumps were inoperable. The viscosity of the feed slurry increased from 550 cp to as high as 4000 cp. Feed temperature was increased from 193 to 227 °C, and later to 255 °C. Transfers of feed slurry from P-7 to P-2 often had to made manually because of the blocked transfer line.

Also during Condition 9, the K-1 right-side ebullation pump was off line for about two hours for repairs, and both K-1 hot checks were purged with extra PFL by the buffer pumps. Hydrogen flow was lost to the K-1 feed line when a restriction developed, but it was restored to the alternative entry point at the reactor inlet.

Condition 10 (Periods 39 through 41)

In Condition 10 the coal and TNPS feed were eliminated and the Hondo resid feed was reintroduced at 2011 gm/hr. The L-858 plastics feed rate was increased to 223 gm/hr, and the PFL recycle rate was decreased to 312 gm/hr. This change was completed by 2200 hours Period 39, and the TNPS feed was eliminated at 0400 hours Period 40. There were two 400 gm acid washes of O-1 and O-1A during Period 39.

There was some feed disruption at the start of Condition 10, but otherwise it proceeded smoothly. The spare slurry feed pump was needed, and the slurry feed was discontinued for 30 minutes until a blockage in the hydrogen feed to K-1 cleared. Additional buffer oil was charged to improve diminished flow to K-1 left-side hot checks.

Conditions 11 (Periods 42 through 43)

At 0400 hours of Period 42, plastics feed was discontinued, and the feed rate of Hondo resid was increased to give the same total feed rate. Operations were generally smooth during Condition 11 with only minor problems. The top and bottom zone temperatures of K-1 had to be adjusted when the middle zone stopped heating. Viscous material caused temporary restrictions in the P-7-to-P-2 transfer line and the bottoms-receiver inlet line.

On-Line Time Summary

The chronology of the operations for Run 227-91 is listed in Table A, along with a summary of the total time in startup, run, shutdown, and down modes. Unit 227 operated continuously for 1139 hours for an on-line efficiency of 100 %.

Shutdown and Inspection

Shutdown commenced at the end of Period 43 (0400 hours January 10, 1996). During the cool-down and wash period, there was a continuation of the O-1 level control problems, and a blockage developed in the line between O-3 and O-6 (bottoms receiver).

The process equipment was generally in good condition, but there was evidence of some of the problems that occurred during the run. There were solids in the K-1 hydrogen inlet check valve, which had caused the restriction in Condition 9. An unremovable plug between the two air-operated block valves in the first-stage-sample recycle flow had prevented putting the sample system back on line after collecting the sample for Condition 1. Heavy material impeded clearing some of the K-2 recycle lines. The K-2 recycle knockout vessels were especially plugged with hard solids.

The K-2 catalyst bed was normally settled. The level was 89 1/2 inches compared to the original charge at 84 3/8 inches. Most of the hydrotreater catalyst was in-place, but 79 g was found downstream on the O-2 bottom head.

Table A

RUN 227-91 OPERATIONS-STATUS-CLASSIFICATION CHRONOLOGY

Operations Group I.D.	Start Time	Start Date	End Time	End Date	Duration, Hours
S/U	0200	11/25	0400	11/28	74
1-43	0400	11/28	0400	1/10/96	1032
S/D	0400	1/10	1300	1/11	33

ON-LINE TIME AND DOWN TIME FOR RUN 227-91

Time of Initial S/U & Final S/D, Hours	Time of Intermediate S/Ds & S/Us, Hours (No. of Int. S/D-S/U Pairs)	Total On-Line Time, Hours	Down-Time, Hours	On-Line Efficiency, %
107	0 (0)	1139	0	100.0

Definitions:

S/U = Startup. Time between gas flow initiation and feedstock cut-in during which unit temperatures and/or pressures are being increased.

S/D = Shutdown. Time between feedstock cut-out and liquid flow termination during which unit temperatures and/or pressures are being decreased.

Run-Periods = Time during which the unit is at run conditions and the operations is identified with a Period number.

On-Line Time = The sum of S/Us, S/Ds, and Run-Periods.

Down-Time = The time during which gases and liquids are not being charged to the unit. This is the same as the time between an intermediate shutdown and startup.

On-Line Efficiency = On-Line Time / (On-line Time + Down-Time)

OPERATING CONDITIONS AND MATERIAL BALANCES

Overall bench run operations were smooth and without any major issues or problems. The exact feed composition, in terms of relative amounts of coal, Hondo resid, and waste plastics for different run conditions, is depicted in *Figure 2*. An average material recovery balance (the daily material balance summary is attached in the Appendix) of about 99.4 W% was obtained (*Figure 4*) for the entire Bench Run PB-02. The Operating Summary and the Process Performance of individual Periods during PB-02 are shown in *Table 6a and 6b*. *Figure 3* shows the operating conditions during PB-02 in terms of feed space velocities and reactor temperatures. As shown in *Figure 3*, the increased reactor temperatures during Periods 11 and 23 were accompanied by increases in feed space velocity in order to maintain the overall process thermal severity. The space velocity of the total feed was adjusted during the conditions employing Hondo resid to account for the fact that this heavy oil fraction contained about 82 W% resid (524°C+) material.

PROCESS PERFORMANCE RESULTS

Conversions, yields, process performance, and product quality for PB-02 are addressed in this Section.The calculation of daily material recovery balances, coal conversions, normalized product yields, and other process performance-related indicators were carried out using programs available in the CTSL database (some programs were also modified as per the requirement of the process configuration for PB-02). Overall process performance during PB-02 is summarized in *Tables 6a and 6b,* depicted in *Figures 5* through *10,* and discussed in detail in the following sections.

Total Feed and 524°C+ Residuum Conversion

Typical feed conversions (based on the solubility of pressure filter cake in quinoline), obtained from equilibrated periods of different conditions of PB-02 are shown in *Figure 5.* As shown in this Figure, feed conversions (W% maf feed) varied beween about 88 to 99.6 % maf during the run. During 'coal-only' feed conditions, conversions varied between 90.2 and 93.7 W% maf. The newly tested concept of "interstage" internal recycle did not improve coal conversions. Changing the type of feed from coal-only to combinations of coal/resid, conversions increased slightly. During conditions when no coal was present in the feed, the total conversions were as high as 99 W%+ maf, indicating that little or no char (quinoline insoluble material) was formed in the reactors.

As shown in *Figure 5*, residuum conversion varied between 72.0 to 88.0 W% (maf feed). The larger spread in the residuum conversions is partly attributed to the deactivation of the supported extrudate catalyst in the second stage reactor. The steady decline in residuum conversion values continued as the run progressed. Interstage internal recycle had no noticeable effect on conversion of resid to lighter products. During combined feed or 'coprocessing' conditions involving Hondo resid, residuum conversions held between 75-80 W% maf. These comparitively lower resid conversions are partly attributed to the nearly "once-through" mode of operation during Hondo resid coprocessing, where the unreacted resid did not get recycled to increase conversion.

C_4-524°C Distillate and 524°C+ Residuum Yields

Distillate yields and 524°C+ residuum yields are shown in *Figure 6*. The distillate yields varied between 57 and 64 W% maf, during the 'coal-only' feed conditions. Distillate yields were not affected by the interstage internal recycle. Upgrading of Hondo resid alone resulted in as high as 72 W% maf distillate yield. The yield dropped to about 64-68 W% maf during the coal/oil coprocessing condition. Unlike earlier bench runs with waste plastics in feed with coal, with the introduction of small amounts of waste plastics (10 W%) in the feed (during Conditions 38 and 41) results in a slight decrease in distillate yields to 57-66 W%. The 524°C+ residuum yield varied between 3.5 to 27 W%, with higher residuum yields obtained during conditions when the recycle ratio was reduced from 1 to 0.17 and the second stage supported catalyst had deactivated.

Distillate Fraction Yields

The yields of distillate fractions such as naphtha (IBP-177°C), middle distillates (177-343°C), and heavy distillates (343°C+) are shown in *Figure 7*. The numbers plotted in this Figure, converted to a selectivity basis, are shown in *Figure 8*. As shown in *Figures 7 and 8*, the heaviest distillate fraction (343°C+) increased as the run progressed, tracking supported catalyst deactivation. Yield of this heavy fraction was also higher during conditions that processed Hondo resid alone or with coal and plastics, probably because of the reduced recycle. The light naphtha and middle distillate fractions were between 40-50 W% maf throughout the operation. The conditions employing interstage internal recycle have resulted in higher selectivities of the lightest naphtha fraction.

Hydrogen Consumption and Light Gas (C_1-C_3) Yield

Hydrogen consumption *(Figure 9)* based on maf feed, varied between 0.8 and 7.5 W%. During 'coal-only' conditions, chemical hydrogen consumption varied only a little (between 6 - 7.5 W%). Hydrogen consumption decreased significantly (1.7 W%), as expected, when feeding Hondo resid alone ; the consumption was also low (3-4.5 W%) during the 'coal/oil coprocessing' condition. Interestingly, the addition of small amounts of waste plastics (10 W%) coal or heavy oil feed reduced the hydrogen consumption compared to 'coal-only' or heavy oil-only' processing. The addition of plastics to the feed also resulted in a significant reduction in the formation of light gaseous products (C_1-C_3). This observation, regarding the capping role of plastics in the feed, is similar to the results from CMSL-09, 10, 11, and PB-01 bench runs.

Hydrogen Utilization

Hydrogen utilization during coal conversion is characterized by two indicators: hydrogen efficiency and C_1-C_3 gas selectivity. The former is defined as the amount of C_4-524°C distillate obtained per unit weight of hydrogen consumed, while the latter is the weight of light hydrocarbon gases produced per unit weight of distillate. As shown in *Figure 10*, the hydrogen efficiency improved substantially when coal was coprocessed with Hondo resid and waste plastics; similarly, the light gas selectivity dropped significanrtly in going from 'coal-only' feed to coprocessing or feeding Hondo resid alone. This behavior establishes the beneficial role of organic wastes, such as MSW plastics and Hondo resid, in substantially improving hydrogen utilization during coal conversion with a net positive impact on the overall economics.

PRODUCT QUALITY

Product fractions (product gases, SOH, PFL, and PFS) from Work-up Periods 3, 7,10, 14, 18, 22, 26, 30, 34, 38, 41, and 43 were analyzed in detail. These analyses are listed in *Table*s 7 through 12.

Separator Overhead Product (SOH)

The SOH oil stream represents the net light distillate (IBP-343°C) from PB-02. While the hydrotreater was on-line during the run, the only major distillate product stream was the SOH stream, as the O-1 hot separator overheads, the ASOH (when the atmospheric still was on-line), and the unit knockouts were being fed directly to the hydrotreater. The properties of SOH oil for the work-up periods are shown in *Table 7*. The SOH oils had a typical boiling range of 50-380°C. The API gravities were high (> 45), and the H/C atomic ratios were also high (> 1.95), especially during coal-waste coprocessing and resid hydrocracking. The heteroatom levels (nitrogen and sulfur) were low throughout the run, indicating very successful operation of the in-line hydrotreater. Typically, sulfur levels below 50 ppm and nitrogen levels were below 1 ppm were obtained for the SOH oil. The quality of SOH distillates (heteroatom content and H/C ratios) is depicted in *Figures 11 and 12.*

Pressure Filter Liquid (PFL) and Pressure Filter Solids (PFS)

The separator bottoms go through pressure filtrations for separation of solids from heavy liquid product and recycle oil. The oil, called pressure filter liquid (PFL), is usually heavier than 343°C boiling point and contains unreacted heavy residuum material to varying degrees. The oil-containing cake from filtration, PFS, is normally extracted with toluene for oil recovery, and the oil-free solids are then used for determining the extent of coal and total feed conversion based upon the solubility of the PFS material in a solvent such as quinoline. The detailed analyses of the PFL and PFS streams from PB-02 are listed in *Table*s 8 and 9. The PFS stream that is analyzed during the bench run contains about 20-25 W% of oil extractable with toluene. The oil extracted using toluene from the PFS also becomes the net product from the process as it is not used for recycle when sufficient pressure filter liquid is present.

The PFL API gravity was low for all the 'coal-only' feed conditions, decreasing as the run progressed and tracking second stage reactor catalyst deactivation. The API gravities increased during the coprocessing and resid hydrocracking conditions. At the same time, the hydrogen content of the PFL increased significantly from about 6.8 % to about 12.5 % in going from 'coal-only' feed operation to coprocessing and resid hydrocracking conditions (*Figure 12*). This observation confirms the positive impact of coprocessing organic wastes with coal on the overall hydrogen content of the products. The 524°C+ residuum content of the PFL are between 35-40 W% throughout the run. The preasphaltenes and asphaltenes in the PFL, characterized by its insolubilities in toluene and cyclohexane respectively (*Figure 13*), also decreased substantially in making the transition from 'coal-only' feed operation to coprocessing and resid hydrocracking.

Analysis of True Boiling Point (TBP) Fractions

The primary net distillates from Bench Run PB-02 were the hydrotreated SOH products. These products were selected from three equilibrated work-up periods, 10, 34, and 43, to represent the 'coal only', 'coal+oil', and 'oil only' feeds during PB-02, respectively, all without any interstage internal recycle. The detailed analyses of the TBP fractions from these Periods is shown in Table 10 through 12. In all the cases shown, the lightest naphtha fraction (IBP-177°C) of the products has low aromaticity, high hydrogen content, high API gravity, and very low heteroatom content. This fraction can, therefore, make an ideal source for blending into finished transportation fuels with minimal further refining/treatment. Even the mid-distillate fraction (177-260°C) is of high quality for production of low-sulfur diesel or jet fuel. Thus, the net distillates from Bench Run PB-02 are of premium quality and have the potential to find their disposition readily into the existing refining market.

DISCUSSION OF PROCESS PERFORMANCE RESULTS

(I) Effects of Interstage Internal Recycle

One of the primary objectives of Bench Run PB-02 was to study the effect of a novel interstage internal recycle. This involved recycling part of the second stage reactor effluent (at operating temperature and pressure) back to the first stage reactor. This mode of operation moved the overall reaction system toward more back-mixing at the expense of plug-flow behavior. The idea behind attempting the interstage internal recycle was the concept that the aromatic compounds generated in the higher temperature first stage reactor would be hydrogenated in the lower temperature second stage reactor, making it easier to crack them when recycled back to the higher temperature first stage reactor. No significant impact of interstage internal recycle was found except that the yield of the lightest naphtha fraction had increased substantially during the conditions of PB-02 that practised the interstage internal recycle. As shown in *Figure* 14, after accounting for deactivation of the second stage supported catalyst, overall process performance (feed and residuum conversions, distillate yields, and light gas-makes) for periods with internal recycle was similar to that obtained without any internal recycle. The quality of the product was also not affected significantly by the internal recycle. A favorable distiilate fraction selectivity toward naphtha was obtained along with slightly lower gas-make during the conditions employing internal recycle. In this manner, the overall interstage internal recycle, despite the increased levels of back-mixing, was not found to deteriorate the overall process performance.

(II) Operations with Hybrid Catalyst

In the recent past, several bench runs have been conducted which have established the effectiveness of HTI's new iron based dispersed slurry catalysts for hydrocracking of carbonaceous materials, including coal, heavy oil, waste plastics, and combinations thereof. Bench run PB-02 was designed to study the effectiveness of a "hybrid" catalytic mode of operation, in which dispersed slurry catalyst is added to the stage 1 feed while the second stage reactor is an ebullated bed reactor with conventional supported extrudate catalyst. *Figure 15* compares the performance of the hybrid mode with an "all-dispersed catalyst" operation. For three different feedstocks, the all-dispersed catalyst system resulted in slightly better performance than the hybrid catalyst. It is well known that supported catalyst, however active at the begining of a run, looses activity rapidly on stream, primarily by carbon deposition and mineral matter or metal poisoning. Unless replaced periodically, supported catalyst becomes ineffective during the course of the process. Dispersed catalysts, which are used on a once-through or disposable basis, do not suffer this deactivation problem. The operations are also simplified when ebullated supported catalysts are replaced with easy-to-suspend, fine-sized, high-surface-area, dispersed slurry catalysts such as those used during PB-01. It is evident from recent bench runs that, if an in-line hydrotreater is provided for aromatics saturation and heteroatom removal, then satisfactory coal and residuum conversions can be achieved using dispersed catalysts only.

(III) Role of Waste Plastics Additives on Coal or Heavy Oil Hydrocracking

It is believed, based upon the results from bench runs feeding coal co-mingled with plastics from municipal solid wastes, that addition of plastics helps reduce light gas make and, therefore, decreases hydrogen consumption. Thus, mixed waste plastics, consisting of different proportions of HDPE, polypropylene, and polystyrene, are speculated to have a "suppressive" role on the gas-forming radicals produced during the hydroconversion of coal and heavy oil. This hypothesis was further tested with smaller proportions of mixed plastics in the feed (10 W%), during PB-02. As shown in *Figure* 16, for both types of feedstocks (coal-only and oil-only), the addition of mixed plastics resulted in a substantial reduction in the hydrogen consumption and light hydrocarbon gas production (more than that expected due to the reduced percentage of coal (or resid) in the feedstock.

TECHNO-ECONOMIC ASSESSMENT

Feed to bench run PB-02, as for in PB-01, contained Black Thunder coal, Hondo heavy oil and mixed waste plastics. However, instead of the all-dispersed catalyst used in PB-01, this run used a hybrid catalyst system, namely dispersed catalyst in the first reactor stage and supported catalyst in the second. Dispersed catalyst rate and composition was the same as in PB-01, namely 50 ppm Molyvan A and 5,000 ppm Iron. This run employed a high/low reactor temperature staging (high first stage temperature, low second stage) instead of the low/high staging in PB-01.

Five conditions in PB-02 were examined. Conditions 1 and 2 (Periods 7,10 and 14) used an all-coal feed, condition 3 (Period 34) used a coal/oil mixture and condition 4 (Period 38) used a coal/plastics feed. Condition two differed from condition 1 in having hot-separator bottoms recycle to the first-stage reactor, as a means of increasing the residual oil residence time. For Condition 1, Period 7 was operated at a low space velocity than Period 10.

Table 13 presents material balances, and *Table* 14 summarizes hydrogen balances, utilities production and thermal efficiencies for the five run conditions examined. Liquefaction plant investment details are listed in *Table* 15. The three coal-only conditions require considerably higher investments than coal/oil and coal/plastics operation. The benefit of higher space velocity operation is shown by the reduced liquefaction plant cost from Period 7 to Period 10.

Total plant investments for the three coal-only conditions are significantly higher than the mixed coal feed conditions, as seen in *Table* 16. The use of higher space velocity, in Condition 1 resulted in higher gas yield, which significantly increased the cost of the treating plant.

Economics are summarized in *Table*s 17 and 18. Operation with coal/plastics is somewhat beneficial while coal/oil operation is definitely advantageous. In coal only operation, the benefit of lower cost in liquefaction due to the higher space velocity is negated by the higher treating costs. No advantage is gained by internal recycle.

Figure 17 compares economic results of PB-2 with those of PB-1, showing a stand-off in coal-only operation and marginally higher cost in PB-2 for coal/oil operation.

Table 19 compares coal-only operation in the two catalyst modes at nearly identical reactor conditions, showing a virtual standoff in economics. The hybrid case produces less heavy 454° C+ material than the all-slurry case, resulting in more hydrogen production via steam reforming. Steam reforming reduces capital requirement, but is seen to increases fuel and catalyst requirements.

Significant savings could be realized if catalyst consumption were reduced. In coal-only operation, a 50 percent reduction in catalyst usage would reduce the equivalent crude oil price by $1.20/B. It is suggested that such reduction be attempted in future runs.

In summary, economic assessment of PB-02 results show the benefit of mixed coal/oil operation. Use of the hybrid catalyst system appears to be a stand-off with the all-dispersed system. No advantage was found for hot-separator recycle.

CONCLUSIONS

The following conclusions can be drawn based upon the data obtained from Bench Run PB-02:

1. Interstage internal recycle of the type implemented during PB-02, with high-low reactor temperature-sequencing, did not have any negative impact on process performance, despite it leading to increased reactor backmixing. Interstage internal recycle showed a distinct advantage in distillate fraction selectivity toward naphtha, and a slight improvement in gas-make for coal-only operation. The fact that the overall process performance was maintained during the interstage internal recycle mode of operation, despite it leading to increased back-mixing, has a positive implications when a reactor scale-up is considered.

2. In general, the hybrid catalyst system, in which dispersed catalyst is added to the first stage reactor feed with the second stage as an ebullated bed reactor with supported catalyst, was almost as effective in achieving high levels of process performance as the all-dispersed catalyst reactor system tested in the earlier bench runs.

3. Addition of small amounts of mixed plastics to either coal or heavy oil improved hydrogen utilization during their hydroconversion reactions by reducing the light gas make and hydrogen consumption.

4. Economic assessment of PB-02 results show a slight advantage of using an all dispersed catalyst system with low/high staging, as in PB-1, over the hybrid system with high/low temperature staging used in PB-2.

Table 1. Run Plan for Bench Run PB-02

Condition	1A	1B	2	3*	4*	5*	6*	7	8	9	10	11
Periods	1-3	4-7	8-10	11-14	15-18	19-22	23-26	27-30	31-34	35-38	39-41	42-43
W-Up Period	3	7	10	14	18	22	26	30	34	38	41	43
Temp., K-1, ° C	441	449	454	454	454	454	449	449	449	449	449	449
Temp., K-2, ° C	432	432	432	432	432	432	441	441	441	441	441	441
Interstage Separator	343	343	343	343	343	343	343	343	343	343	343	343
In-line Hydrotreater	379	379	379	379	379	379	379	379	379	379	379	379
Feed Sv, Kg/h/m³ Xtr	641	641	801	801	801	1058**	1058**	801	801	801	801	1058**
Catalysts												
K-1	---------- 5000 ppm of HTI's Iron Catalyst and 50 ppm Molyvan-A----------											
K-2	----------Supported NiMo/Alumina Akzo AO-60 Catalyst ----------											
Feeds, W%												
Coal	100	100	100	100	50	0	0	5	50	90	0	0
Hondo Resid	0	0	0	0	50	100	100	95	50	0	90	100
Mixed Waste Plastic	0	0	0	0	0	0	0	0	0	10	10	0
Recycle solvent/Feed	1	1.00	1.00	1.00	0.17	0.17	0.17	0.17	0.17	1	0.17	0.17

* During Conditions 3-6, about 10-20 W% of the second stage reactor internal recycle will be directed with feed to the first stage reactor.
**Since the Hondo VTB contains about 82 W% 524 °C+ Resid, the space velocity for resid is 865 Kg/hr/m³ reactor.

Table 2. Analysis of Feed Black Thunder Mine coal

HTI Designation	HTI 6213
Moisture Content, W%	10.01
Proximate Analysis, W% Dry	
Volatile Matter	43.48
Fixed Carbon	50.52
Mineral Matter	6.00
Ultimate Analysis, W% Dry	
Carbon	70.12
Hydrogen	5.11
Nitrogen	0.99
Sulfur	0.35
Ash	6.19
Oxygen (Diff.)	17.24
H/C Atomic Ratio	0.875

Table 3. Analysis of Feed Heavy Oil and Waste Plastics

Feed Type	Hondo VTB Resid	Waste Plastics
Gravity, API°	6.2	N/A
524°C+ Resid Content, V%	82.0	N/A
Ultimate Analysis, W% Dry		
Carbon	83.84	80.51
Hydrogen	10.13	11.42
Nitrogen	0.90	0.00
Sulfur	4.39	0.21
Oxygen	0.59	6.06
Ash	0.15	1.64
Chlorine	N/A	0.16

Table 4. Analysis of Start-up/Make-up Oil

HTI Designation	Filtered L-814
API Gravity, °	0.40
ASTM D-1160 Distillation, °C	
IBP	309
5 V%	351
10 V%	374
20 V%	394
30 V%	409
40 V%	426
50 V%	437
60 V%	449
70 V%	467
80 V%	507
84 V%	524
Weight Percents	
IBP-343°C	5.47
343-454°C	53.99
454-524°C	22.18
524°C$^+$	18.36
Elemental Analysis, W%	
Carbon	88.96
Hydrogen	8.25
Sulfur	2.22
Nitrogen	0.19
NMR Data	
W% Aromatic Carbon	88.03
W% Cyclic Hydrogen	44.36

Table 5. List of Samples Provided to Consol, Inc.

Sample Description	*Typical Amount, g*	*Periods*
Feed Slurry	250	7, 10, 14, 18, 22, 26, 30, 34, 38, and 41
CAS Bottoms	350	7, 10, 14, 18, 22, 26, 30, 34, 38, and 41
SOH Oil	250	7, 10, 14, 18, 22, 26, 30, 34, 38, and 41
Pressure Filter Solids	350	7, 10, 14, 18, 22, 26, 30, 34, 38, and 41
Pressure Filter Liquid	250	7, 10, 14, 18, 22, 26, 30, 34, 38, and 41

Table 6a. Run 227-91: Process Performance Summary

Period Number	3	7	10	14*	18*	22*
Hours of Run	72	48	120	216	312	408
Dispersed Catalyst ppm*: Fresh Mo			50			
Fresh Iron			5000			
Feed Composition, W%						
Coal	100	100	100	100	50	0
Waste Plastics	0	0	0	0	0	0
Hondo Resid	0	0	0	0	50	100
Space Velocity, kg/h/m^3 react	750	665	769	878	857	1099
Second Stage Catalyst Age, kg feed/kg cat.	184	414	644	872	1112	1356
Temperatures, °C						
First Stage	446	447	453	452	452	450
Second Stage	418	427	428	429	429	429
Material Balance (%) (gross)	95.21	94.17	98.10	97.38	104.01	98.23
Estimated Normalized Yields, W% Dry Fresh Feed						
C_1-C_3 in Gases	8.40	9.76	12.25	11.05	6.00	4.34
C_4-C_7 in Gases	3.46	3.92	5.34	8.02	2.81	2.55
IBP-177°C in Liquids	16.03	15.67	13.41	15.95	9.83	10.81
177-260°C in Liquids	13.35	10.54	10.90	8.15	11.87	15.65
260-343°C in Liquids	15.18	13.96	14.97	9.37	12.63	12.42
343-454°C in Liquids	10.75	11.53	9.95	9.35	17.20	19.05
454-524°C in Liquids	1.70	2.56	1.54	2.69	7.79	11.44
524°C+	3.5	4.57	4.42	9.67	16.5	19.29
Unconverted Feed	7.52	9.24	7.07	7.88	4.43	0.12
Ash	5.75	5.75	5.75	5.75	2.95	0.14
Water	14.24	13.47	10.73	11.98	7.23	1.57
CO	0.77	0.88	1.01	1.20	0.61	0.04
CO_2	4.41	4.33	7.40	3.47	1.22	0.02
NH_3	0.97	0.96	0.98	0.84	0.49	0.66
H_2S	-0.16	-0.08	-0.23	-0.04	1.78	3.66
Hydrogen Consumption	5.87	7.07	5.49	5.32	3.35	1.77
Process Performance, W% MAF Feed						
Feed Conversion	92.0	90.2	93.7	91.6	95.4	99.9
C_4-524°C Distillate Yield	64.2	61.7	59.5	56.8	64.0	72.0
C_4-524°C Distillate Yield[1]	64.2	61.7	59.5	56.8	60.5	65.9
524°C+ Conversion	88.3	85.3	87.8	81.1	78.4	80.6

*Using internal recycle from Second Stage Reactor to First Stage Reactor.
[1]Total distillate yields are expressed on a net 524°C+ feed basis.
**Since the Hondo VTB contains about 82 W% 524°C+ Resid, the space velocity for resid is 865 Kg/hr/m^3 reactor.

Table 6b. Run 227-91: Process Performance Summary

Period Number	26*	30	34	38	41	43
Hours of Run	504	600	696	792	864	912
Dispersed Catalyst ppm*: Fresh Mo	50					
Fresh Iron	5000					
Feed Composition, W%						
Coal	0	5	50	90	0	0
Waste Plastics	0	0	0	10	10	0
Hondo Resid	100	95	50	0	90	100
Space Velocity, kg/h/m^3 react	1000	1062	793	816	1126	1205
Second Stage Catalyst Age, kg feed/kg cat.	1596	1858	2080	2344	2580	2836
Temperatures, °C						
First Stage	447	447	446	446	447	448
Second Stage	438	438	438	438	437	438
Material Balance (%) (gross)	101.12	99.17	97.41	99.74	98.58	98.42
Estimated Normalized Yields, W% Dry Fresh Feed:						
C_1-C_3 in Gases	3.78	4.70	6.28	5.49	3.75	4.47
C_4-C_7 in Gases	2.36	2.98	2.86	2.14	2.28	2.93
IBP-177°C in Liquids	10.30	10.60	12.94	14.26	9.27	9.93
177-260°C in Liquids	14.10	14.36	15.26	8.39	12.13	12.29
260-343°C in Liquids	12.10	11.47	11.50	8.82	7.82	11.37
343-454°C in Liquids	18.12	19.93	16.95	14.74	20.79	20.27
454-524°C in Liquids	12.50	12.82	7.30	5.28	12.74	11.80
524°C+	22.42	19.06	14.85	15.41	27.16	24.14
Unconverted Feed	0.2	0.51	3.28	10.94	0.93	0.28
Ash	0.14	0.43	2.95	5.34	0.84	0.29
Water	1.64	2.42	6.00	11.02	1.58	1.85
CO	0.04	0.11	0.73	0.64	0.05	0.04
CO_2	0.02	0.05	1.17	2.21	0.03	0.02
NH_3	0.69	0.89	0.38	0.44	0.37	0.08
H_2S	3.37	3.27	1.67	-0.34	0.84	1.04
Hydrogen Consumption	1.79	3.61	4.11	4.77	0.59	0.90
Process Performance, W% MAF Feed						
Feed Conversion	99.8	99.5	96.6	88.4	99.1	99.7
C_4-524°C Distillate Yield	69.6	72.5	68.8	56.6	65.6	68.8
C_4-524°C Distillate Yield[1]	62.9	66.8	65.7	56.8	59.0	62.0
524°C+ Conversion	77.3	80.3	81.3	72.2	71.7	75.4

*Using internal recycle from Second Stage Reactor to First Stage Reactor
[1]Total distillate yields are expressed on a net 524°C+ feed basis.
**Since the Hondo VTB contains about 82 W% 524°C+ Resid, the space velocity for resid is 865 Kg/hr/m^3 reactor.

Table 7. Separator Overhead (SOH) Properties

Period	7	10	14	18	22	26	30	34	38	42	43
Gravity, °API	41.7	34.9	41.4	40.8	48.0	48.4	49.2	45.6	45.1	49.4	49.7
IBP, °C	73	61	52	81	52	52	51	56	53	52	54
FBP, °C	361	393	369	382	367	378	381	389	379	387	383
Elemental Analysis											
Carbon, W%	86.04	86.90	86.21	86.17	85.34	85.15	85.45	85.30	86.12	85.35	85.00
Hydrogen, W%	13.82	12.64	13.29	13.43	14.17	14.15	14.29	13.83	13.77	14.44	14.17
Sulfur (Antek), ppm	46.6	116.0	47.2	49.0	82.2	21.0	21.8	25.8	24.9	25.0	21.4
Nitrogen (Antek), ppm	40.2	64.8	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	0.762	<1.0	<1.0
H/C Ratio	1.93	1.75	1.85	1.87	1.99	1.99	2.00	1.95	1.92	2.03	2.00
ASTM D-86 Distillation, Composition, W%											
IBP-177oC	40.8	31.5	46.8	32.3	38.5	39.3	41.3	41.3	48.8	41.9	41.9
177-260oC	24.2	24.6	23.1	33.1	33.4	32.1	31.6	29.7	21.7	30.4	31.4
260-343oC	30.8	32.1	23.2	26.6	22.7	22.0	20.3	21.8	22.0	20.3	20.1
343oC+	4.0	11.4	6.0	8.0	5.3	6.5	6.8	7.2	7.0	6.8	6.4
Loss	0.2	0.4	0.9	0.0	0.1	0.1	0.0	0.0	0.5	0.6	0.2

Table 8. Pressure Filter Liquid (PFL) Properties

Period	7	10	14	18	22	26	30	34	38	42	43
Gravity, °API	2.1	-5.2	-10.3	2.3	12.7	12.3	12.7	8.6	0.1	9.8	11.4
IBP, °C	234	282	255	227	187	201	205	206	250	204	183
Elemental Analysis, W%											
Carbon	89.85	90.40	85.54	88.33	87.02	86.19	87.14	87.21	86.53	85.90	85.69
Hydrogen	8.47	7.57	6.84	8.82	10.29	10.35	12.43	9.60	8.67	10.34	10.08
Sulfur	0.394	0.235	0.595	0.732	1.32	1.78	1.55	0.733	0.415	1.73	1.87
Nitrogen	0.52	0.74	0.85	1.05	1.14	1.15	0.24	1.21	0.93	1.14	1.35
H/C Ratio	1.13	1.00	0.96	1.20	1.42	1.44	1.71	1.32	1.20	1.44	1.41
ASTM D-1160 Distillation, Composition, W%											
IBP-343oC	9.16	6.61	7.79	13.40	20.08	18.90	19.88	22.08	11.44	13.29	17.07
343-454oC	51.94	42.05	32.36	32.55	28.95	25.91	29.05	30.79	33.40	29.07	28.28
454-524oC	13.79	13.13	11.90	17.17	18.86	19.72	20.49	15.25	13.86	20.58	17.78
524oC+	24.74	37.85	47.43	36.79	31.80	35.37	30.48	31.19	40.74	36.96	36.57
Loss	0.37	0.36	0.52	0.09	0.31	0.10	0.10	0.69	0.56	0.10	0.30
Cyclohexane Insolubles, W%	28.49	55.23	67.36	43.67	26.06	23.80	25.91	36.86	56.95	27.99	26.01
Toluene Insolubles, W%	8.41	15.91	36.59	16.04	3.37	1.46	3.75	6.80	31.95	8.27	2.40

Table 9. Pressure Filter Solids (PFS) Properties

Period	7	10	14	18	22	26	30	34	38	42	43
Elemental Analysis, W%											
Carbon	69.19	66.02	68.17	60.62	73.21	67.72	59.42	59.21	65.59	60.93	63.37
Hydrogen	5.24	4.54	4.52	4.40	5.68	4.35	3.98	4.81	4.77	3.72	4.02
Sulfur	2.06	2.30	1.98	3.22	4.89	7.81	8.15	4.55	2.23	8.20	7.74
Nitrogen	0.64	0.69	0.79	0.97	1.91	2.25	1.80	1.07	1.02	1.91	2.17
H/C Ratio	0.91	0.83	0.8	0.87	0.93	0.77	0.8	0.97	0.87	0.73	0.76
Composition, W%											
Quinoline Insolubles	50.45	49.88	44.65	60.45	32.72	41.06	51.94	53.99	60.32	45.23	45.50
Ash (in Quinoline Filt.)	23.19	24.67	22.64	30.28	18.79	13.43	27.75	33.45	24.11	18.49	17.79
Sulfur in Ash	6.61	7.25	6.72	8.29	2.49	1.17	5.66	9.45	7.19	3.13	3.02
ASTM Ash	23.85	24.56	23.13	30.47	20.67	17.35	29.29	34.40	22.89	26.32	22.42
Sulfur in Ash	5.72	6.44	6.32	8.11	2.48	1.71	4.99	9.62	5.87	3.06	2.27
Coal Conversion, W% MAF	93.14	93.17	94.19	93.62	96.31	91.45	95.15	95.96	90.47	94.35	93.27

Table 10. Analysis of TBP Fractions: PB-02 Period 10

TBP Distillation, % IBP = 48°C

	W%
IBP-177°C	34.83
177-260°C	24.08
260-343°C	33.92
343°C$^+$	7.17

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	54.0	31.1	20.3	14.0
Elemental Analysis [W%]				
Carbon	85.26	87.87	88.58	88.87
Hydrogen	14.57	12.37	11.46	10.78
Antek S, ppm	10.9	52.9	302.5	744.8
Antek N, ppm	27.2	76.8	86.5	102.0
Bromine No. [g/100g]	1.68	1.65	1.54	
Aniline Point, [°C]	48.6	29.4	27.5	
Flash Point, [°C]	<-17.8	70	113	
PONA [V%] -				
Paraffins	40.87	10.19		
Olefins	0.60	2.70		
Naphthenics	52.97	49.18		
Aromatics	5.56	37.93		
Aromatics (ASTM D2549)			60.05	

Table 11. Analysis of TBP Fractions: PB-02 Period 34

TBP Distillation, % IBP = 36°C

	W%
IBP-177°C	43.33
177-260°C	27.92
260-343°C	21.25
343°C+	7.50

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	56.7	39.9	32.1	31.3
Elemental Analysis [W%]				
Carbon	84.47	86.73	86.92	86.32
Hydrogen	14.59	13.45	13.30	13.67
Antek S, ppm	3.6	19.8	46.7	319
Antek N, ppm	<0.01	<0.01	0.7	11.7
Bromine No. [g/100g]	1.91	0.97	0.92	
Aniline Point, [°C]	50.8	54.2	66.9	
Flash Point, [°C]	<-17.8	57.8	110	
PONA [V%] -				
Paraffins	46.39	34.49		
Olefins	0.40	1.20		
Naphthenics	47.38	45.96		
Aromatics	5.83	18.35		
Aromatics (ASTM D2549)			24.78	

Table 12. Analysis of TBP Fractions: PB-02 Period 43

TBP Distillation, % IBP = 33.3°C

	W%
IBP-177°C	44.67
177-260°C	29.49
260-343°C	19.92
343°C+	5.92

TBP FRACTION [°C]	IBP-177	177-260	260-343	343+
API Gravity	61.0	43.9	35.8	33.1
Elemental Analysis [W%]				
Carbon	84.29	86.63	86.72	86.49
Hydrogen	15.01	14.27	13.76	14.0
Antek S, ppm	5.1	22.6	50.0	267.0
Antek N, ppm	<0.01	<0.01	1.0	12.7
Bromine No. [g/100g]	1.30	0.79	0.94	
Aniline Point, [°C]	59	62.7	76.4	
Flash Point, [°C]	<-17.8	59	121	
PONA [V%] -				
Paraffins	62.82	46.13		
Olefins	0.50	2.40		
Naphthenics	31.89	38.33		
Aromatics	4.79	13.14		
Aromatics (ASTM D2549)			15.56	

Table 13. Material Balance for Economic Assessment

	Period 7	Period 10	Period 14	Period 34	Period 38
Feed, T/D					
Coal	12,000	12,000	12,000	6,000	10,800
Oil	0	0	0	6,000	0
Plastics	0	0	0	0	1,200
Total	12,000	12,000	12,000	12,000	12,000
Oil, B/D	0	0	0	33,365	0
Liquid Products, B/D					
Gasoline	12,647	12,445	11,755	13,817	11,279
Diesel Fuel	30,714	30,224	28,549	33,557	27,393
Total	43,361	42,669	40,304	47,374	38,672
Barrels Product/Ton feed	3.61	3.56	3.36	3.95	3.22
By-products					
Propane, B/D	4,565	6,523	5,828	2,821	2,659
Butane, B/D	2,500	3,702	2,801	1,848	1,142
Sulfur, T/D	52	50	51	236	47
Ammonia, T/D	115	118	101	46	53
Waste to disposal, T/D	909	915	1,097	932	1,488

Table 14. Hydrogen Balance, Utilities Production and Thermal Efficiency

	Period 7	Period 10	Period 14	Period 34	Period 38
Hydrogen Consumption, MMSCFD					
Liquefaction	342.6	277.9	261.7	199.4	249.5
Product Upgrading	-17.7	37.8	40.2	4.9	-1.7
Solution & Purge Loss	14.9	16.1	15.4	10.3	10.8
Total	339.8	331.8	317.3	214.6	258.6
Hydrogen Production, MMSCFD					
Via Partial Oxidation	152.6	113.2	169.9	214.6	258.6
Via Steam Reforming	187.2	218.6	147.4	0.0	0.0
Total	339.8	331.8	317.3	214.6	258.6
Utilities Produced or Purchased					
Power, Mw	247	233	243	202	242
Steam (600 psig), 1000 lb/hr	161	347	242	321	84
Cooling water, 1000 GPM	157	190	169	156	115
Purchased Natural Gas, 10^9 BTU/D	70.5	96.0	75.9	26.3	38.7
Raw Water, 1000 Gal/D	6,675	8,198	7,924	9,164	6,886
Thermal Efficiency					
Inputs, MMMBTU/Day					
Feed	291.5	291.5	291.5	371.3	306.7
Natural Gas	70.5	96.0	75.9	26.3	38.7
Total	362.0	387.5	367.4	397.6	345.4
Outputs, MMMBTU/D					
Gasoline	70.7	69.6	65.7	77.3	63.0
Diesel	178.3	175.4	165.7	194.9	158.9
Propane & Butane	28.5	41.2	34.6	19.0	15.2
Sulfur & Ammonia	2.7	2.7	2.4	3.0	1.4
Total	280.2	288.9	268.4	294.2	238.5
Thermal Efficiency, %	77.6	74.6	73.1	74.0	69.1

Table 15. Liquefaction Plant Investment Details

	Period 7	Period 10	Period 14	Period 34	Period 38
Major Equipment Cost, $M					
Pumps	23,246	23,801	23,760	19,434	24,189
Reactors & Hydrotreaters	45,390	41,215	37,374	33,790	33,383
Fired heaters	10,319	12,761	13,154	8,119	13,177
Exchangers	21,593	21,539	20,930	16,203	18,815
Drums	38,587	37,399	36,096	27,940	30,577
Towers	8,956	8,931	8,847	6,461	7,759
Compressors	38,145	34,873	33,774	28,387	31,054
HPU	21,457	22,846	22,041	16,605	16,814
Total	207,693	203,365	195,976	156,939	175,768
Plant Investment, $MM					
Equipment & Materials	376.3	368.5	355.1	284.4	318.5
Labor & Subcontracts	162.8	159.4	153.6	123.0	137.8
Indirects	135.5	132.6	127.8	102.4	114.6
Total	674.6	660.5	636.5	509.8	570.9

Table 16. Total Plant Investment Summary
Costs in $MM, 1994 US Gulf Coast basis

Plant Section	Period 7	Period 10	Period 14	Period 34	Period 38
Coal Preparation	239.7	239.7	239.7	137.7	220.4
Oil Storage & Handling	0.0	0.0	0.0	29.9	0.0
Plastics Preparation	0.0	0.0	0.0	0.0	6.4
Liquefaction	674.6	660.5	636.5	509.8	570.9
Hydrogen Manufacture	298.2	292.1	281.9	179.7	204.8
Oxygen Plant	72.8	59.2	78.7	92.4	105.4
Treating	304.9	351.1	328.5	249.4	211.4
Product Upgrading	103.8	109.3	111.5	101.7	111.2
Utilities	301.6	329.5	300.3	307.0	293.5
Tankage, Waste Handling	144.9	143.2	138.8	155.3	138.2
General Offsites	211.0	211.0	211.0	211.0	211.0
Subtotal	2,351.5	2,395.6	2,326.9	1,973.9	2,073.2
Fee, Contingency	469.7	478.6	465.0	394.4	414.1
Total Plant Investment	2,821.2	2,874.2	2,791.9	2,368.3	2,487.3
$/BPSD of Product	65,079	67,360	69,271	49,992	64,318

Table 17. Product Cost Calculation

	Period 7	Period 10	Period 14	Period 34	Period 38
Operating Costs, $MM/year					
Coal, as received ($7.00/Ton)	32.46	32.46	32.46	16.23	29.22
Oil ($8.00/B)	0.00	0.00	0.00	87.68	0.00
Plastics (no cost)	0.00	0.00	0.00	0.00	0.00
Natural Gas ($2.00/MMBTU)	46.30	63.06	49.90	17.26	25.41
River Water ($2.50/Mgal)	5.48	6.73	6.51	7.53	5.65
Waste Disposal ($5.00/Ton)	1.49	1.50	1.80	1.53	2.44
Catalysts & Chemicals	14.17	16.17	12.29	4.79	4.04
Dispersed Catalyst	32.72	32.72	32.72	32.72	32.72
Supported Catalyst	13.30	13.30	13.30	13.30	13.30
Labor	24.43	24.43	24.43	24.43	24.43
Maintenance	21.89	21.89	21.89	21.89	21.89
Capital-Related	419.03	426.06	413.37	357.92	370.04
Total	611.27	638.32	608.67	585.28	529.14
By-Product Credits, $MM/year					
Propane ($12.50/B)	18.75	26.78	23.93	11.58	10.92
Butane ($14.50/B)	11.91	17.63	13.34	8.80	5.44
Sulfur ($52.00/Ton)	0.89	0.86	0.86	4.03	0.80
Ammonia (($120/Ton)	4.54	4.64	3.97	1.80	2.08
Total	36.09	49.91	42.10	26.21	19.24
Net Product Cost, $MM/year	575.18	588.41	566.57	559.07	509.90
Net Product Cost, $/B	40.38	41.98	42.79	35.92	40.14
Crude Oil equivalent Factor	0.851	0.858	0.862	0.831	0.850
Equivalent crude Oil Price, $/B	**34.36**	**36.02**	**36.87**	**29.84**	**34.11**

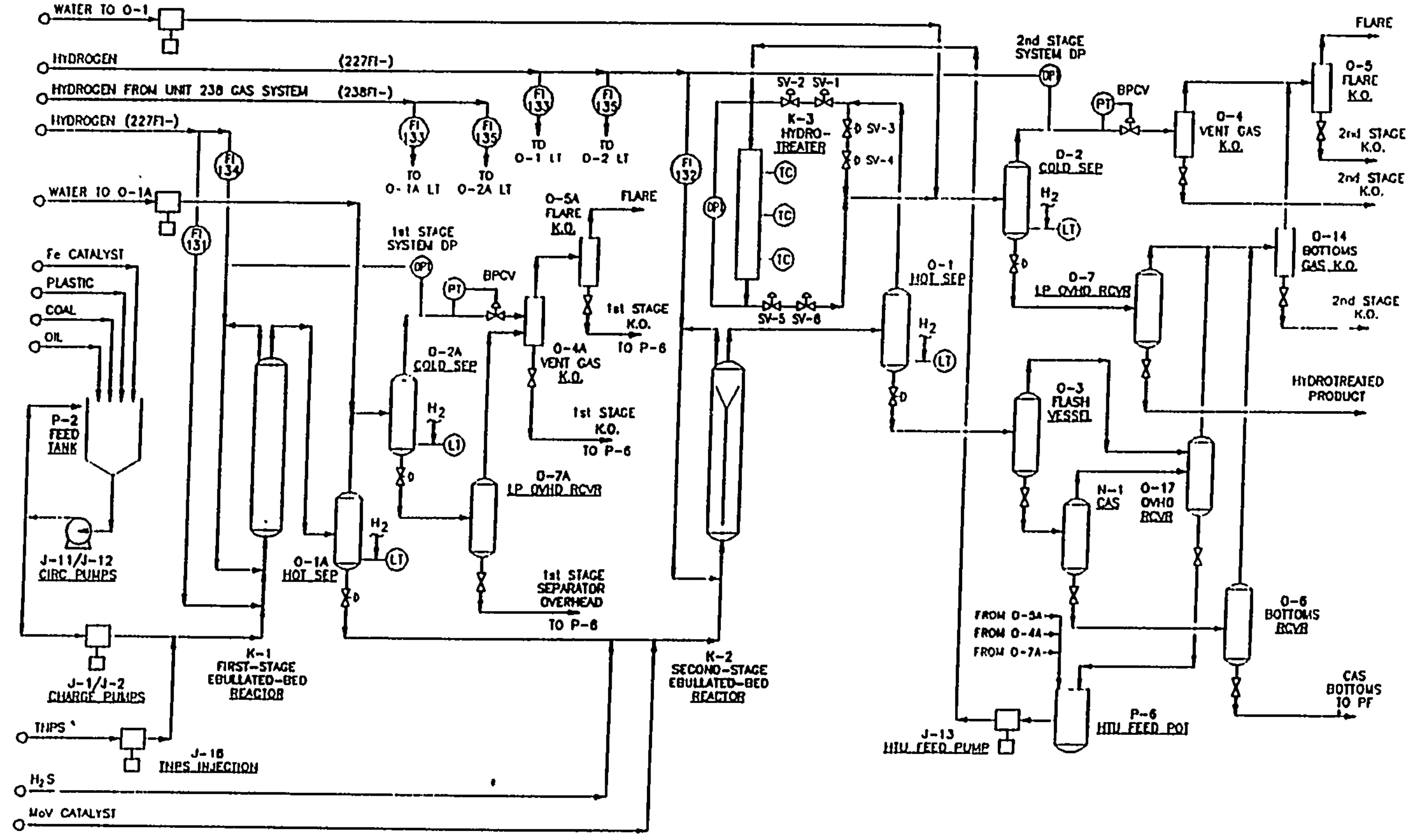
Table 18. Breakdown of Equivalent Crude Oil Price

	Period 7	Period 10	Period 14	Period 34	Period 38
Contribution to Price, $/B					
Coal	1.94	1.99	2.11	0.87	1.95
Oil	0.00	0.00	0.00	4.68	0.00
Plastics	0.00	0.00	0.00	0.00	0.00
Natural Gas	2.77	3.86	3.25	0.92	1.70
Water	0.33	0.41	0.42	0.40	0.38
Waste Disposal	0.09	0.09	0.12	0.08	0.16
Dispersed Catalyst	1.95	2.00	2.13	1.75	2.19
Supported Catalyst	0.79	0.81	0.87	0.71	0.89
Other Catalysts & Chemicals	0.85	0.99	0.80	0.26	0.27
Labor	1.46	1.50	1.59	1.30	1.63
Maintenance	1.31	1.34	1.42	1.17	1.46
Capital-Related Costs	25.03	26.09	26.90	19.10	24.77
By-Product Credit	-2.16	-3.06	-2.74	-1.40	-1.29
Equivalent Crude Oil Price, $/B	**34.36**	**36.02**	**36.87**	**29.84**	**34.11**

Table 19. Comparison of Coal-only operation Cases

Catalyst Configuration	Hybrid	All-Slurry
Space Velocity, kg/hr/m^3	665	694
Operating Temperatures, T_1/T_2 °C	447 / 427	433 / 449
Yields, W% dry coal		
H_2S, NH_3, H_2O, CO_x	20.06	19.43
C_1 - C_4	11.73	14.30
C_5 - 454°C	53.67	53.27
454°C +, ash-free	16.37	13.62
Hydrogen production, MMSCFD		
By Partial Oxidation	153	116
By Steam Reforming	187	230
Liquid Product, B/D	43,361	44,071
Costs, $MM		
Liquefaction plant	674.6	660.9
Hydrogen manufacture	371.0	361.2
Treating	304.7	341.7
Total	2,821.2	2,866.9
Operating costs, $MM/year		
Fuel	46.30	64.56
Supported catalyst	13.30	0.00
Dispersed catalyst	32.72	32.72
Other catalysts & chemicals	14.17	16.73
Capital-related costs	419.03	425.76
Net operating cost	575.18	583.96
Net operating cost, $/B	40.38	40.34
Equivalent crude oil price, $/B	**34.36**	**34.31**

Figure 1. Simplified Schematic of HTI's Bench Unit Configured for Run PB-02



NOTE: EQUIPMENT DESIGNATED O-xA IS FROM 238 UNIT.

Figure 2. PB-02: Feed Composition

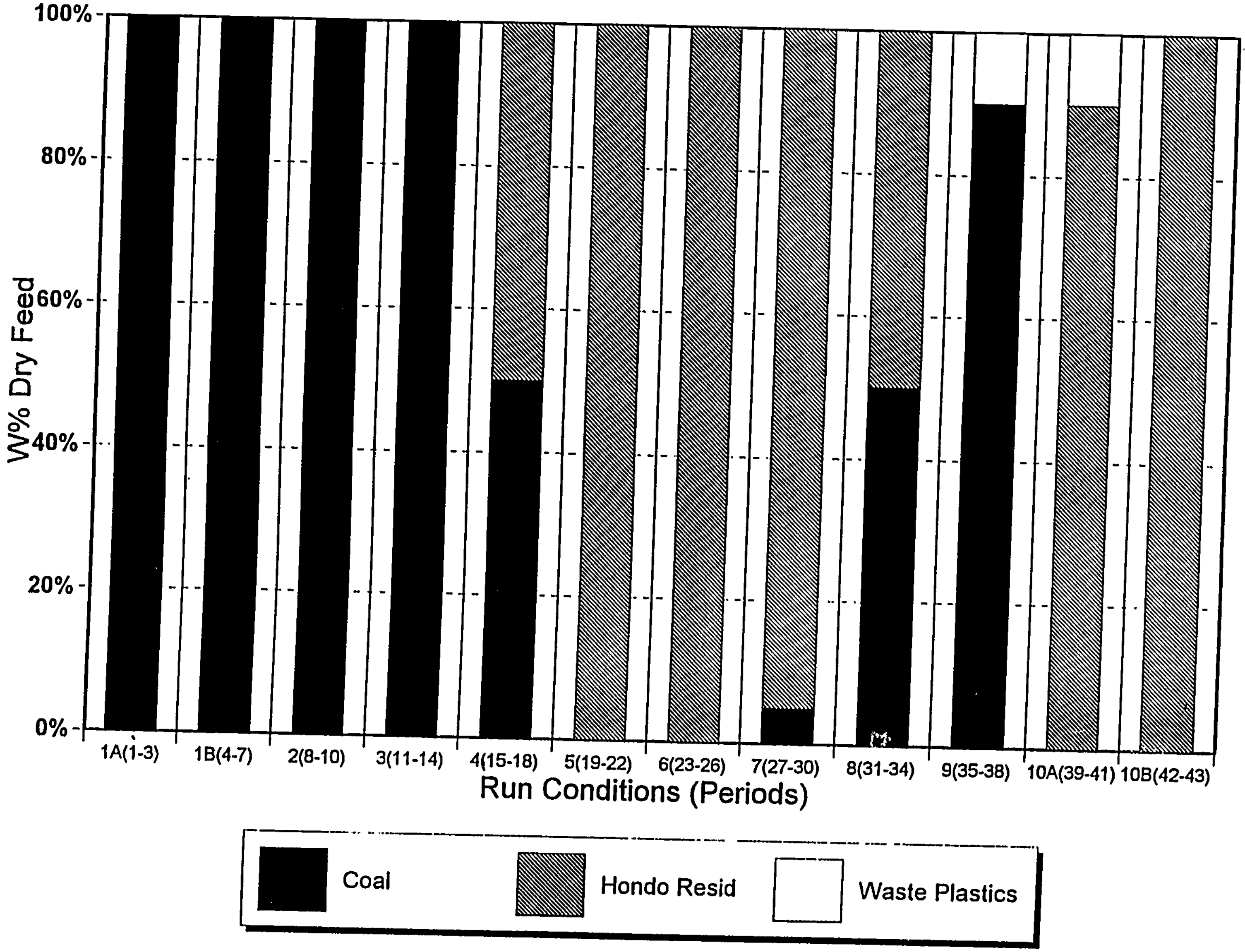


Figure 3. PB-02: Daily Operating Conditions

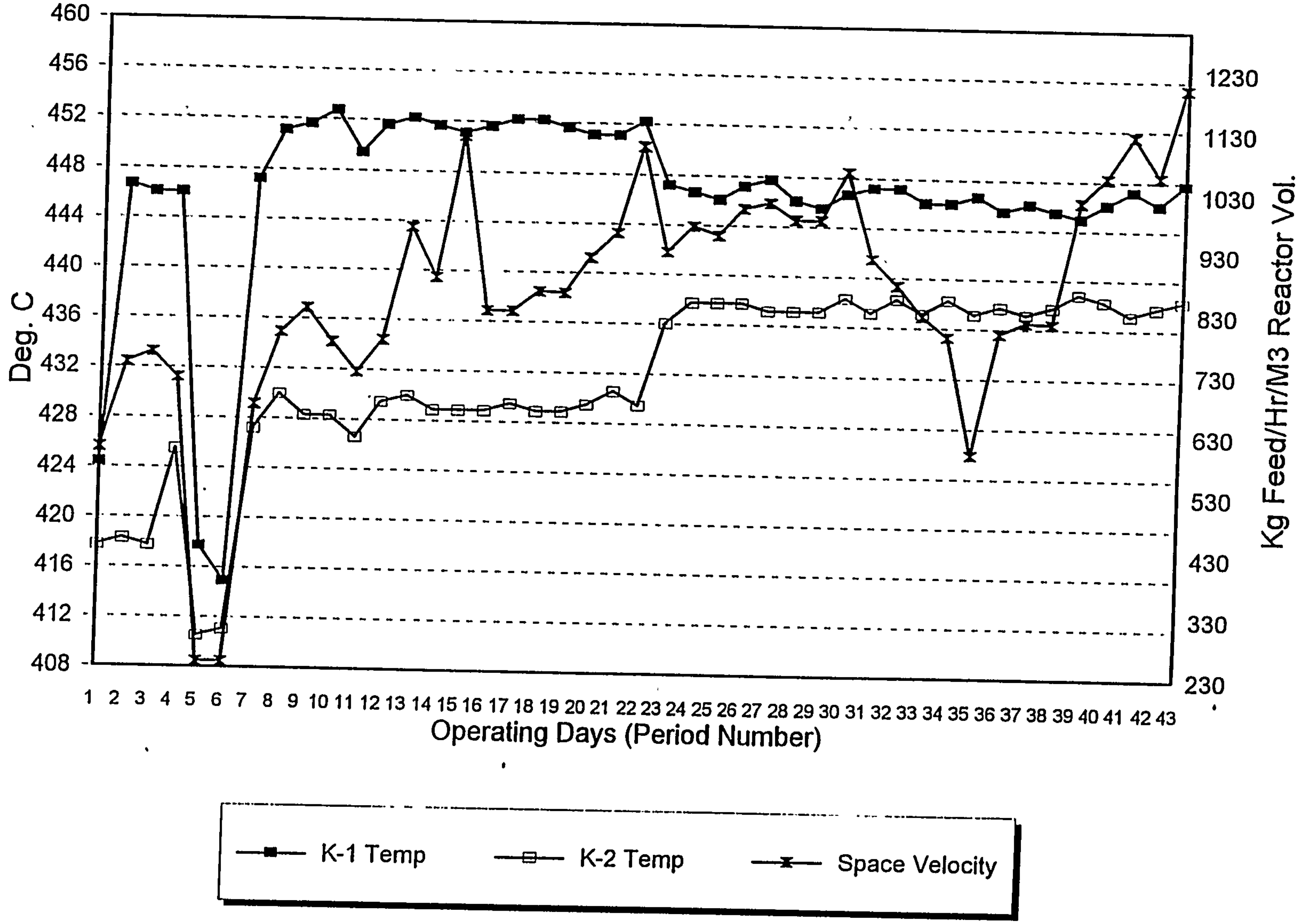


Figure 4. PB-02: Daily Material Recovery Balance

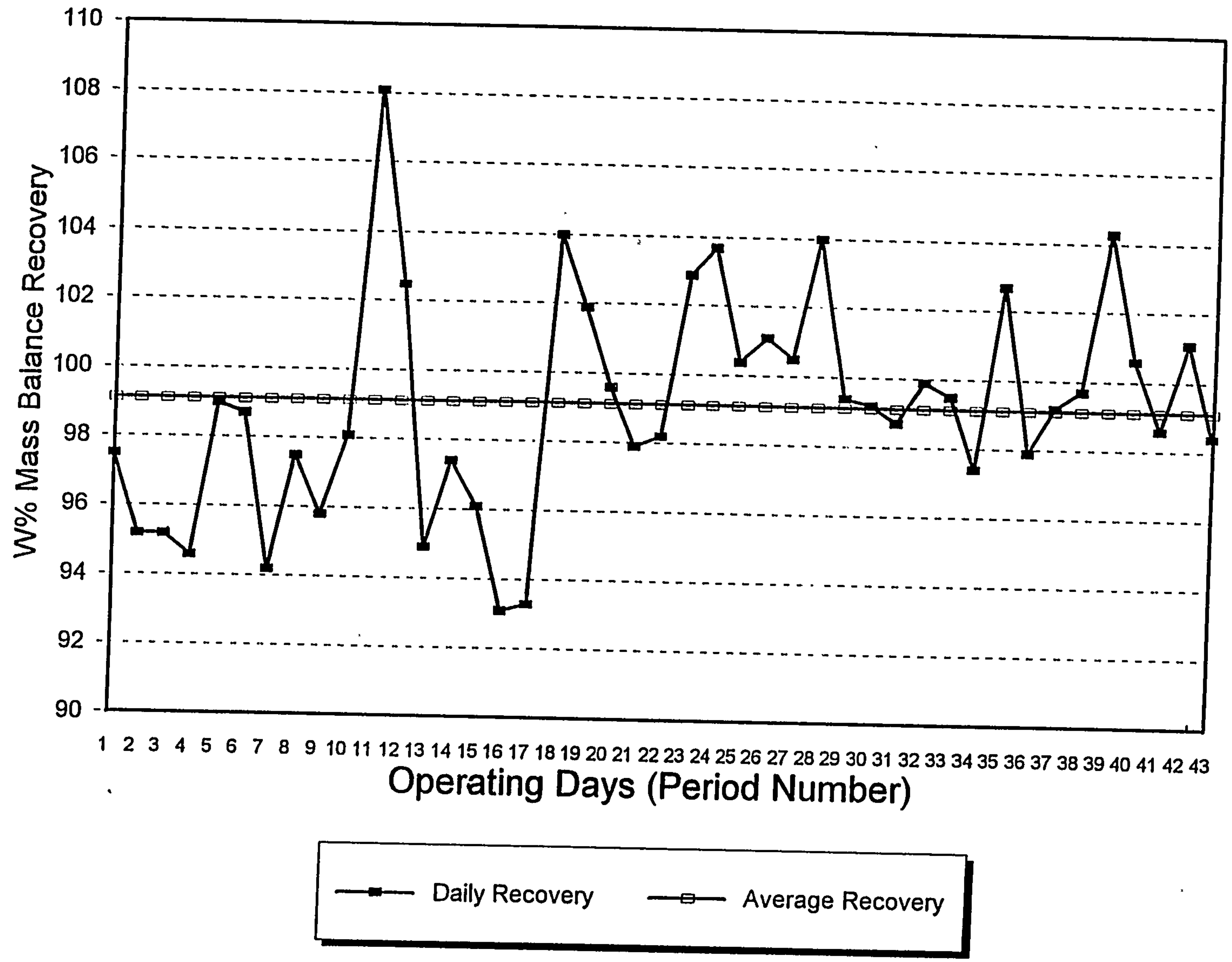


Figure 5. PB-02: Feed and 524°C+ Residuum Conversions

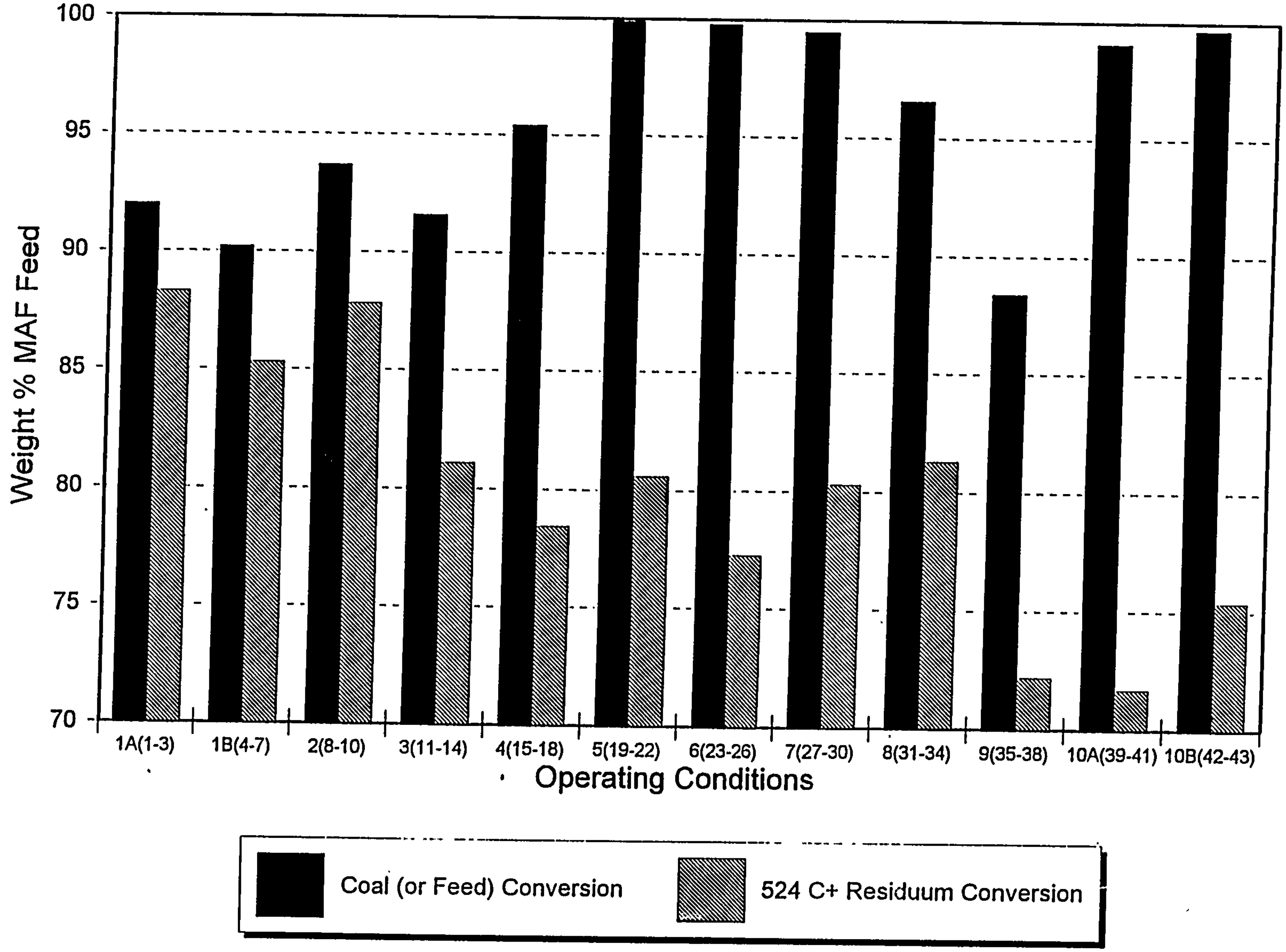


Figure 6. PB-02: C_4-524°C Distillate Yield and 524°C$^+$ Residuum Yield

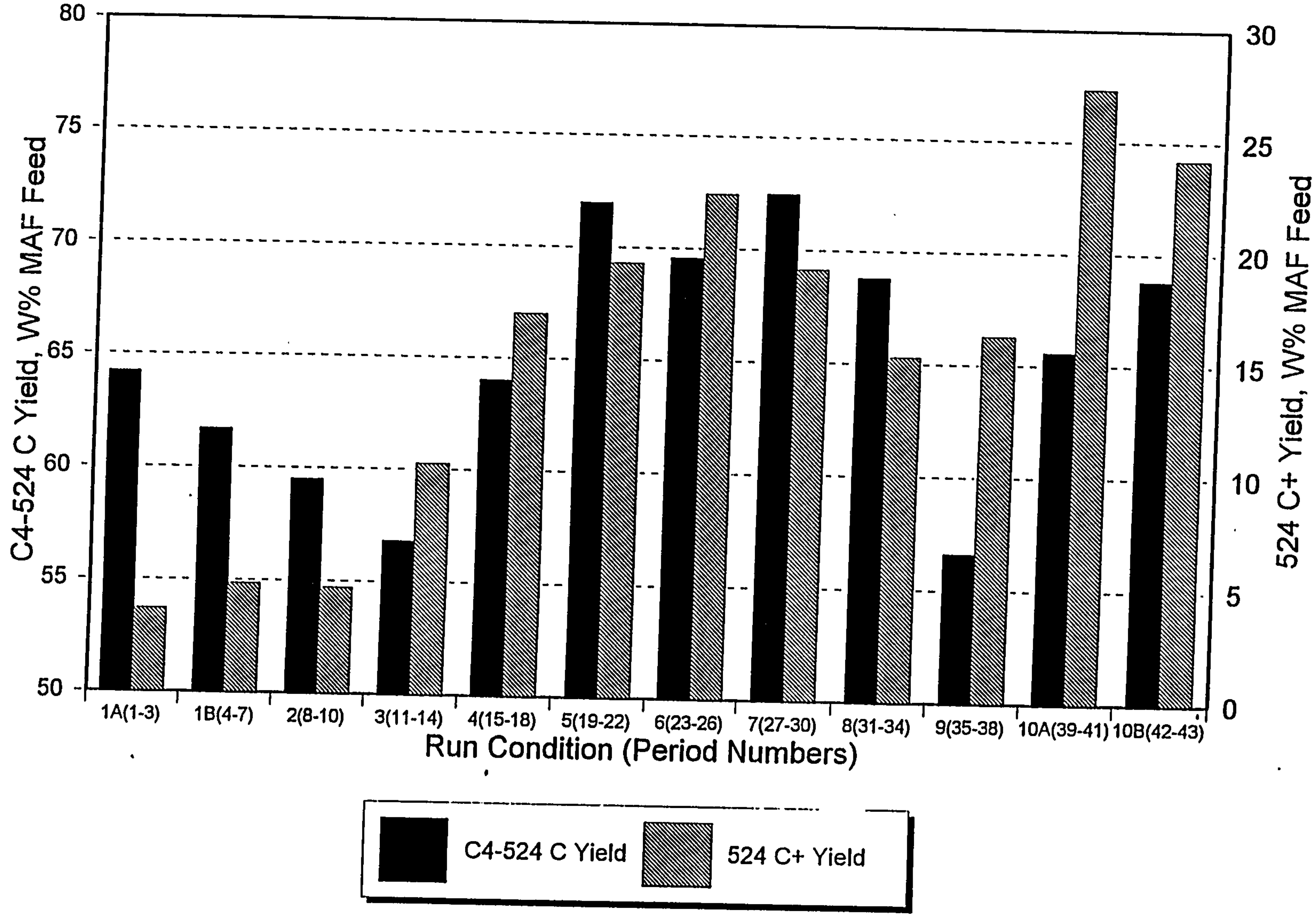


Figure 7. PB-02: Distillate Fraction Yield

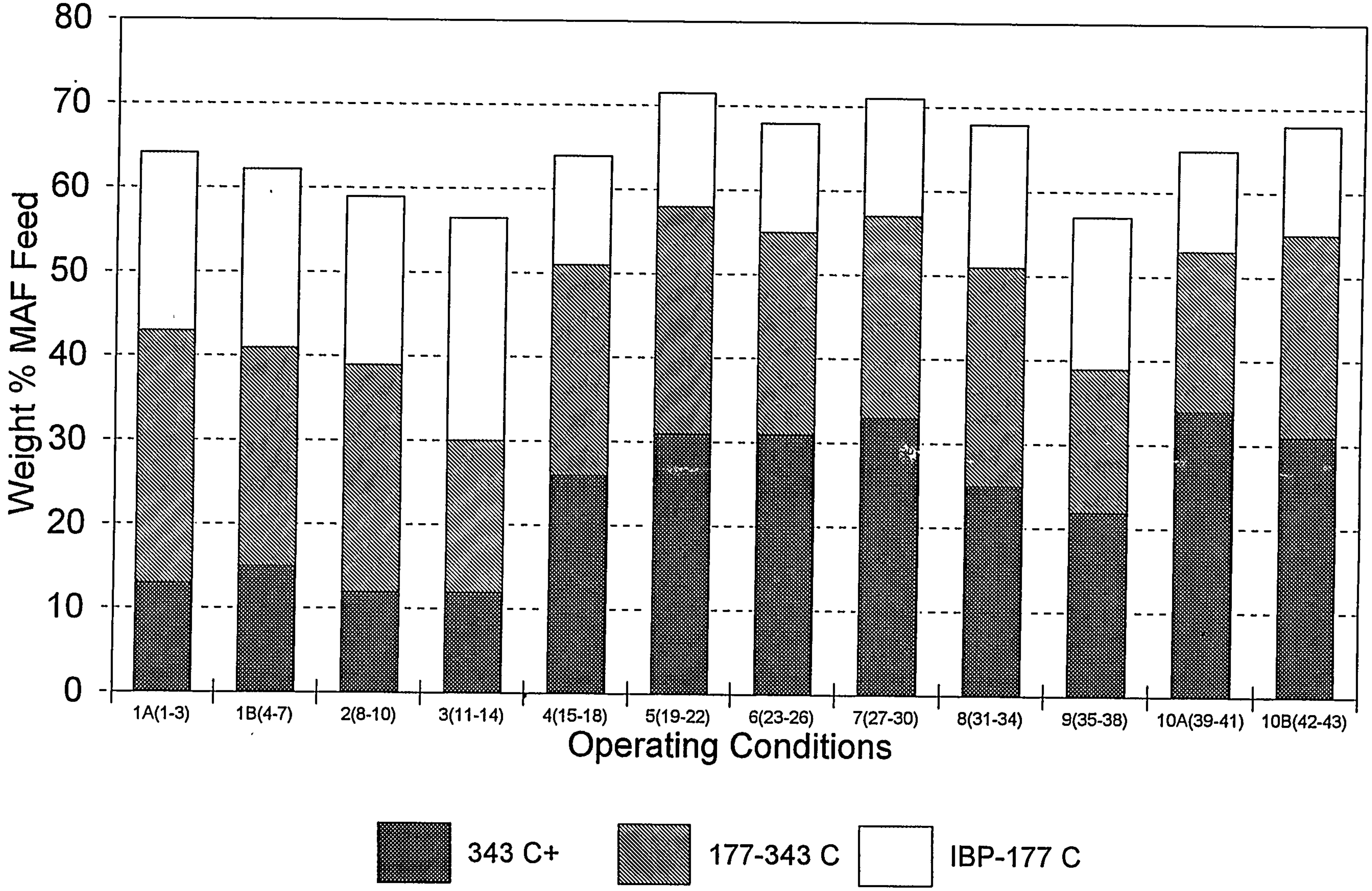


Figure 8. PB-02: Distillate Fraction Selectivity

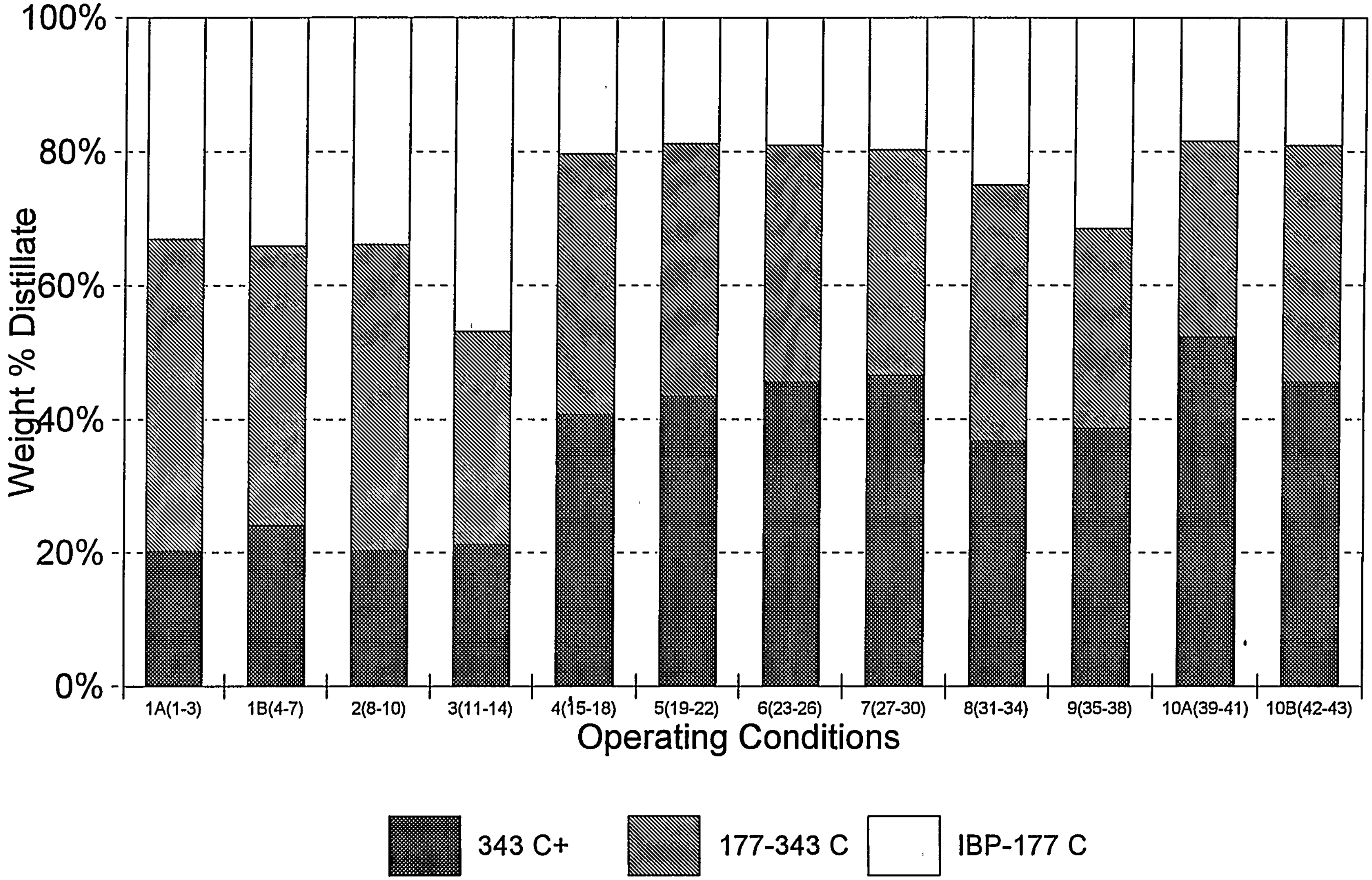


Figure 9. PB-02: Hydrogen Consumption and Light C_1-C_3 Gas Yield

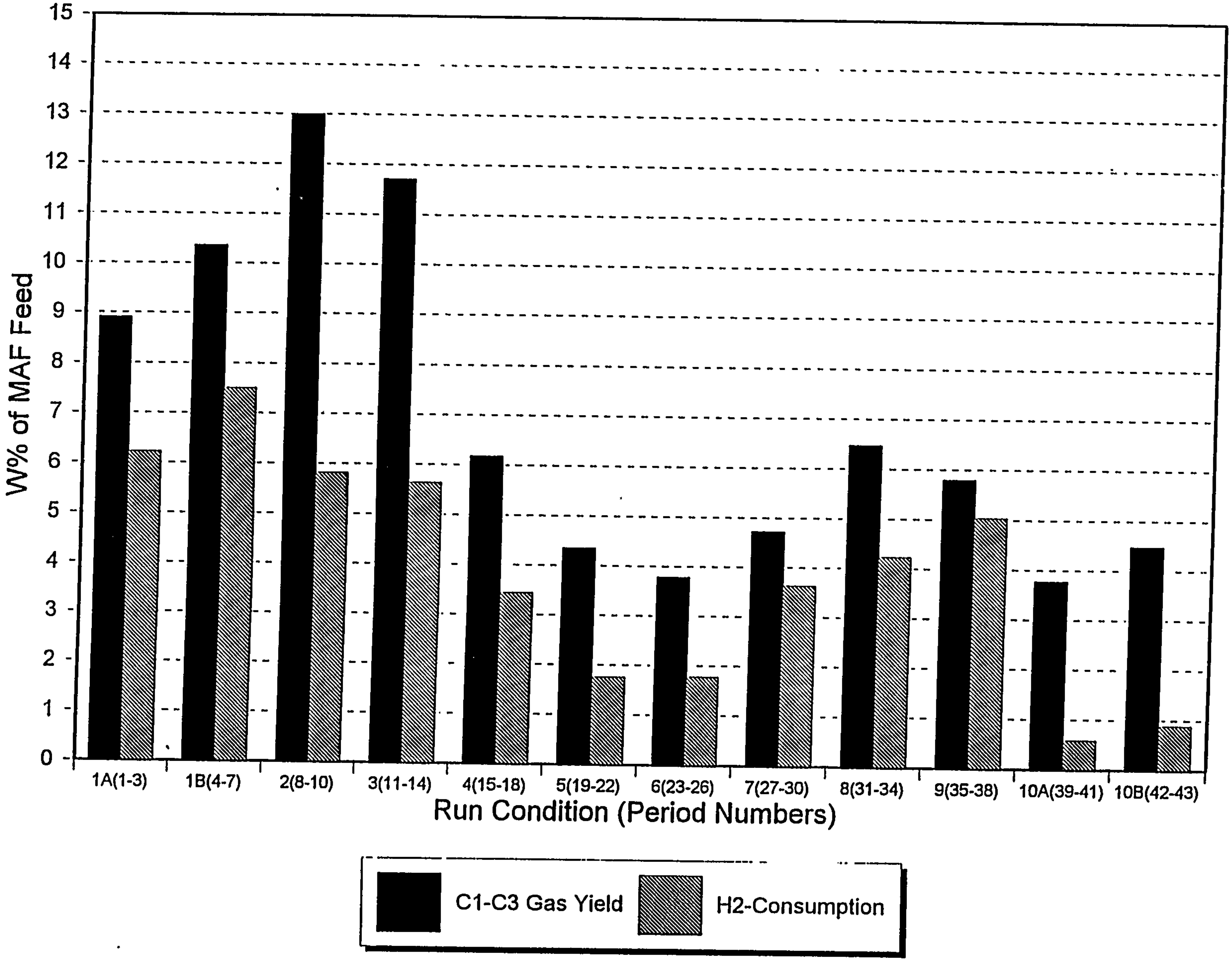


Figure 10. PB-02: Hydrogen Efficiency and C_1-C_3 Gas Selectivity

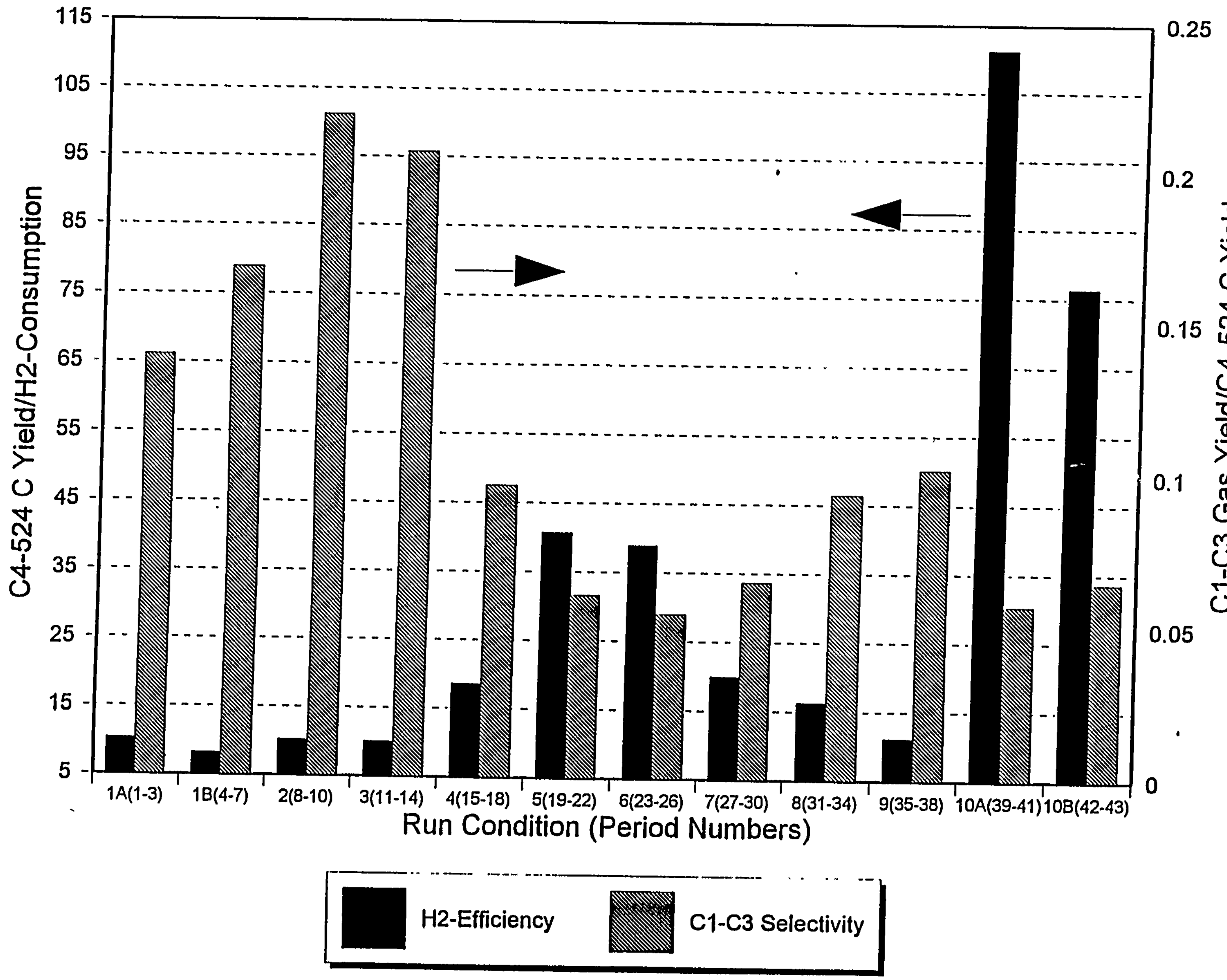


Figure 11. PB-02: Quality of SOH Distillates

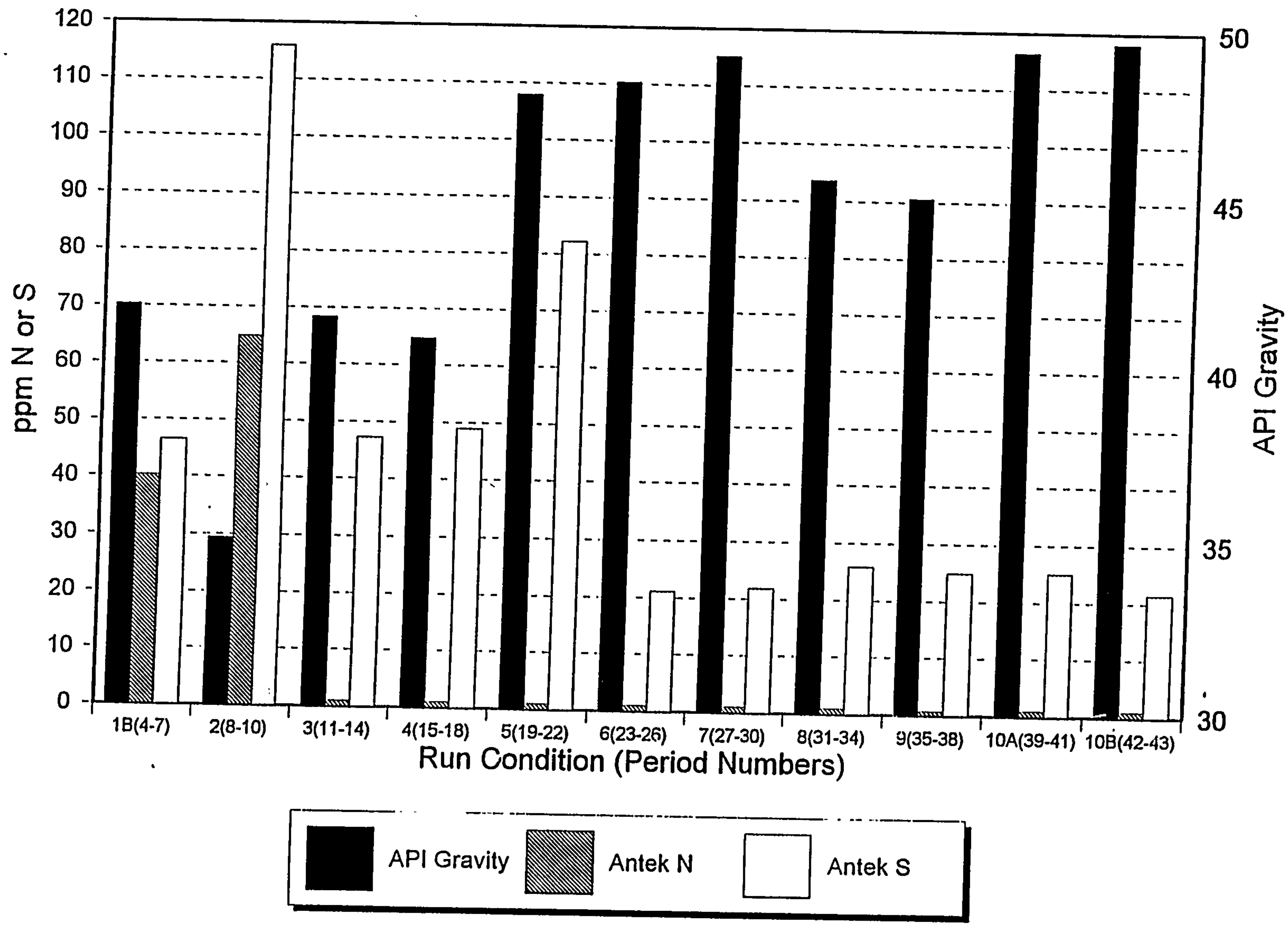


Figure 12. PB-02: Product H/C Ratios

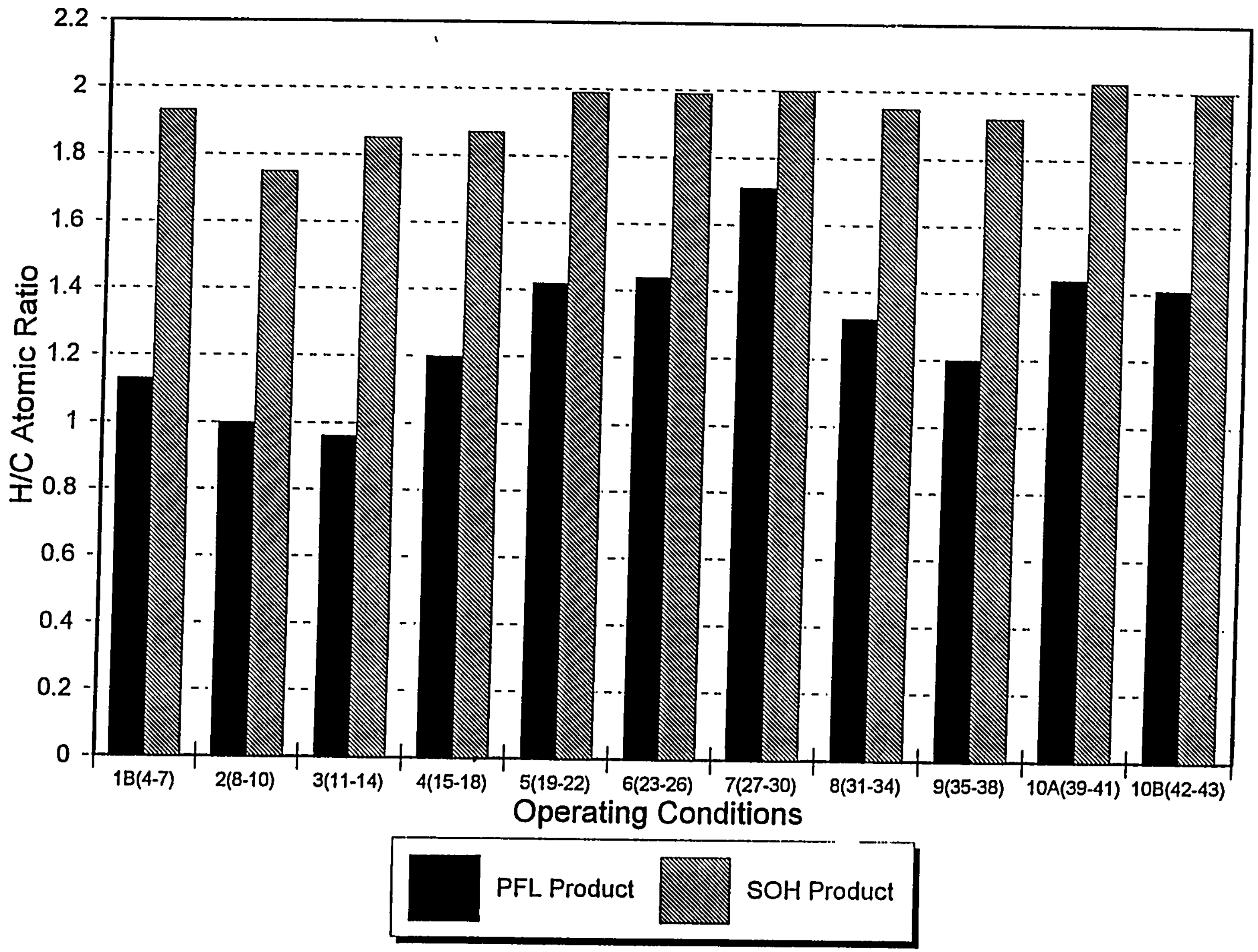


Figure 13. PB-02: Solubility of PFL Product

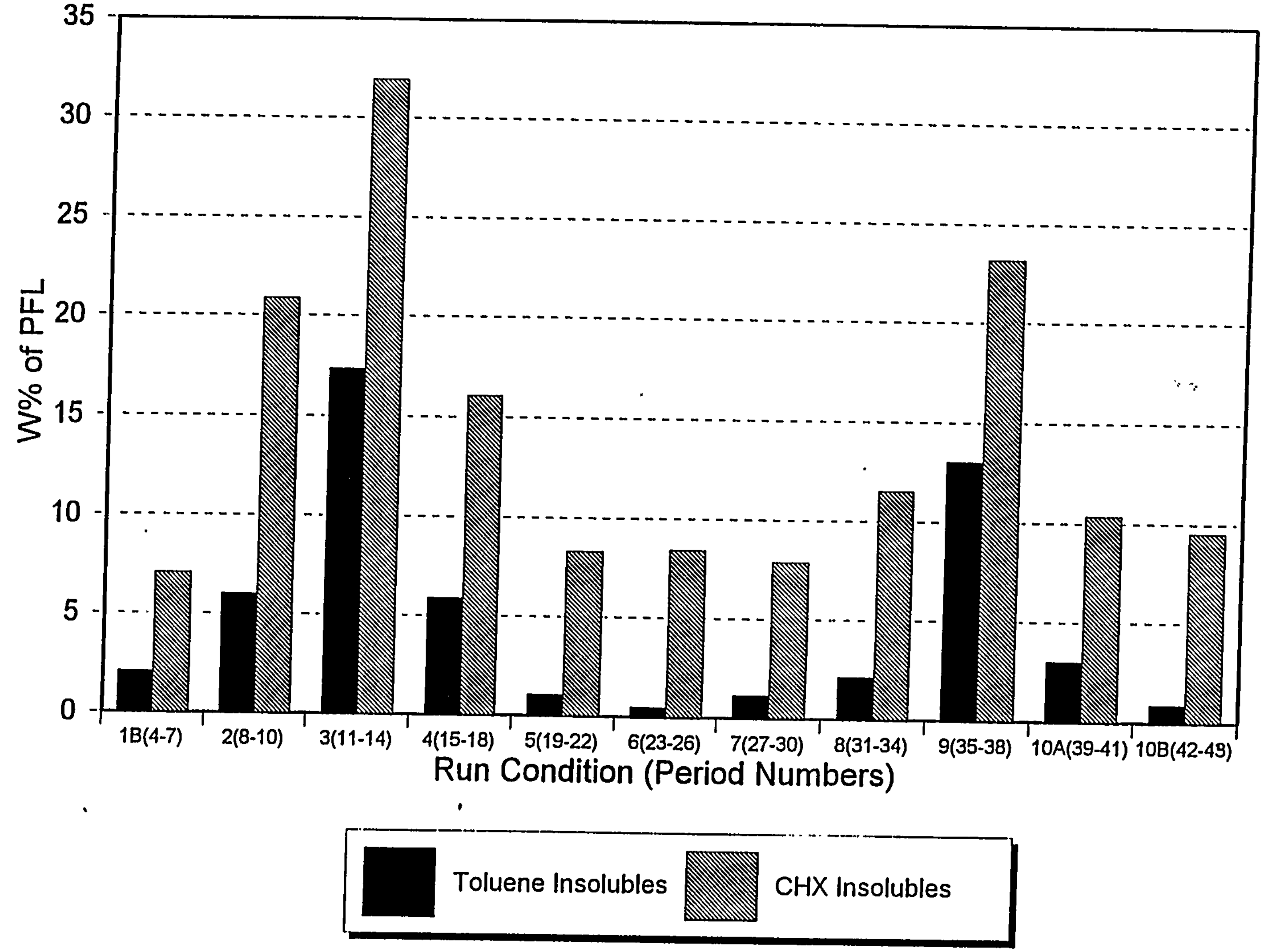


Figure 14. PB-02: Effect of Novel 'Interstage Internal Recycle' on Process Performance

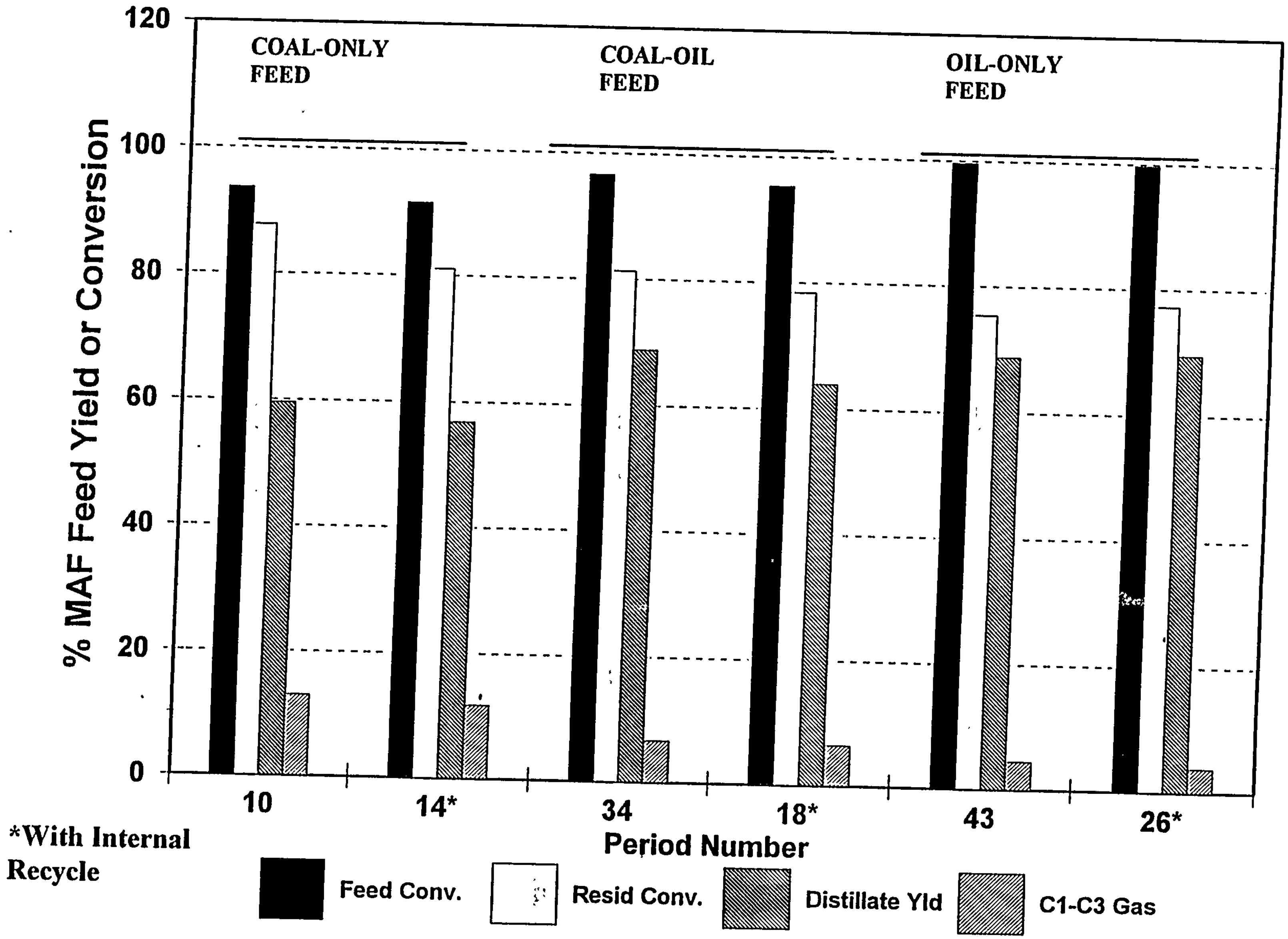


Figure 15. PB-02: Comparison of Process Performance between 'all-dispersed' catalyst mode and 'hybrid' catalyst mode of operation.

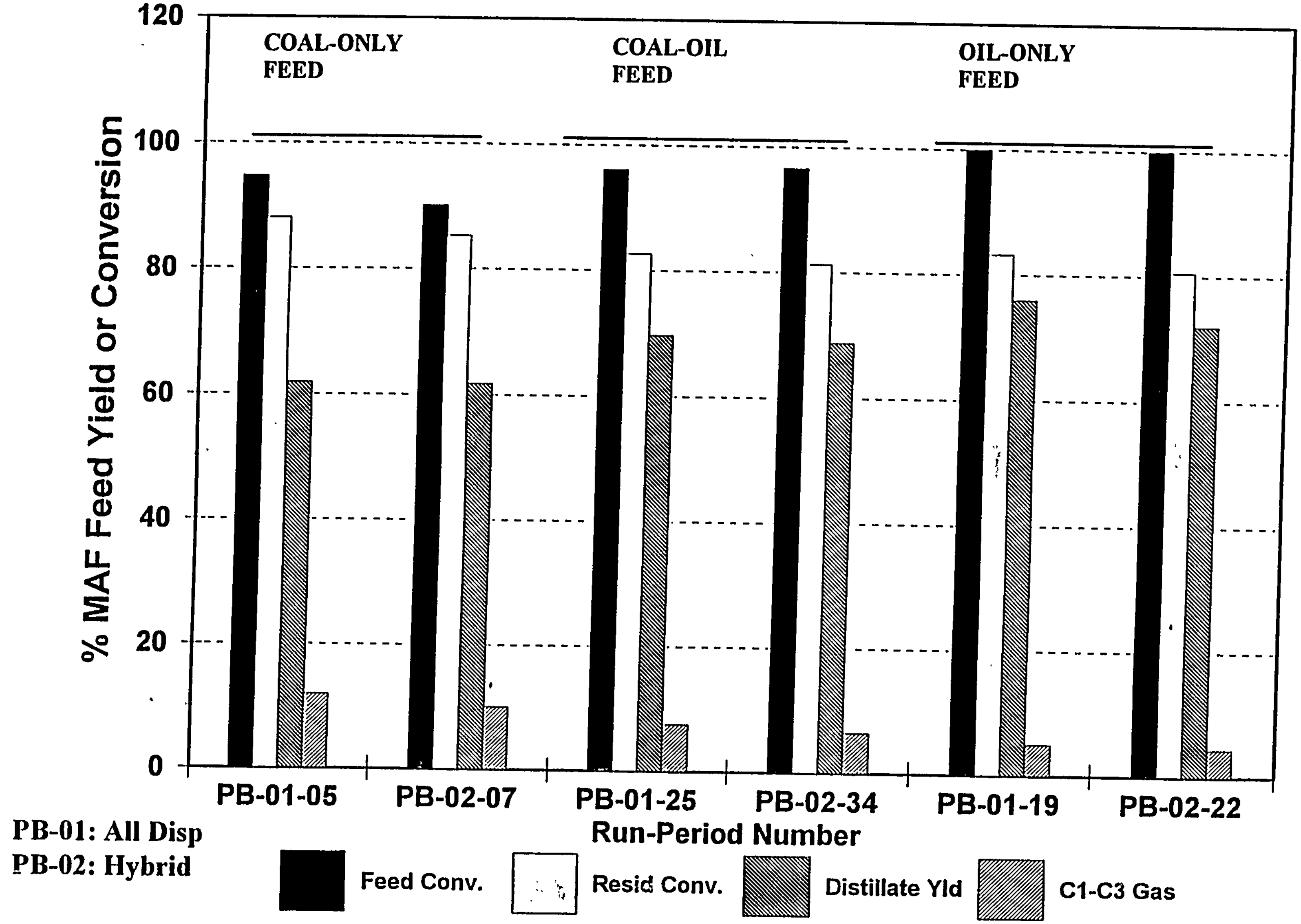


Figure 16. PB-02: Effect of Waste Plastics as Additives on Process Performance

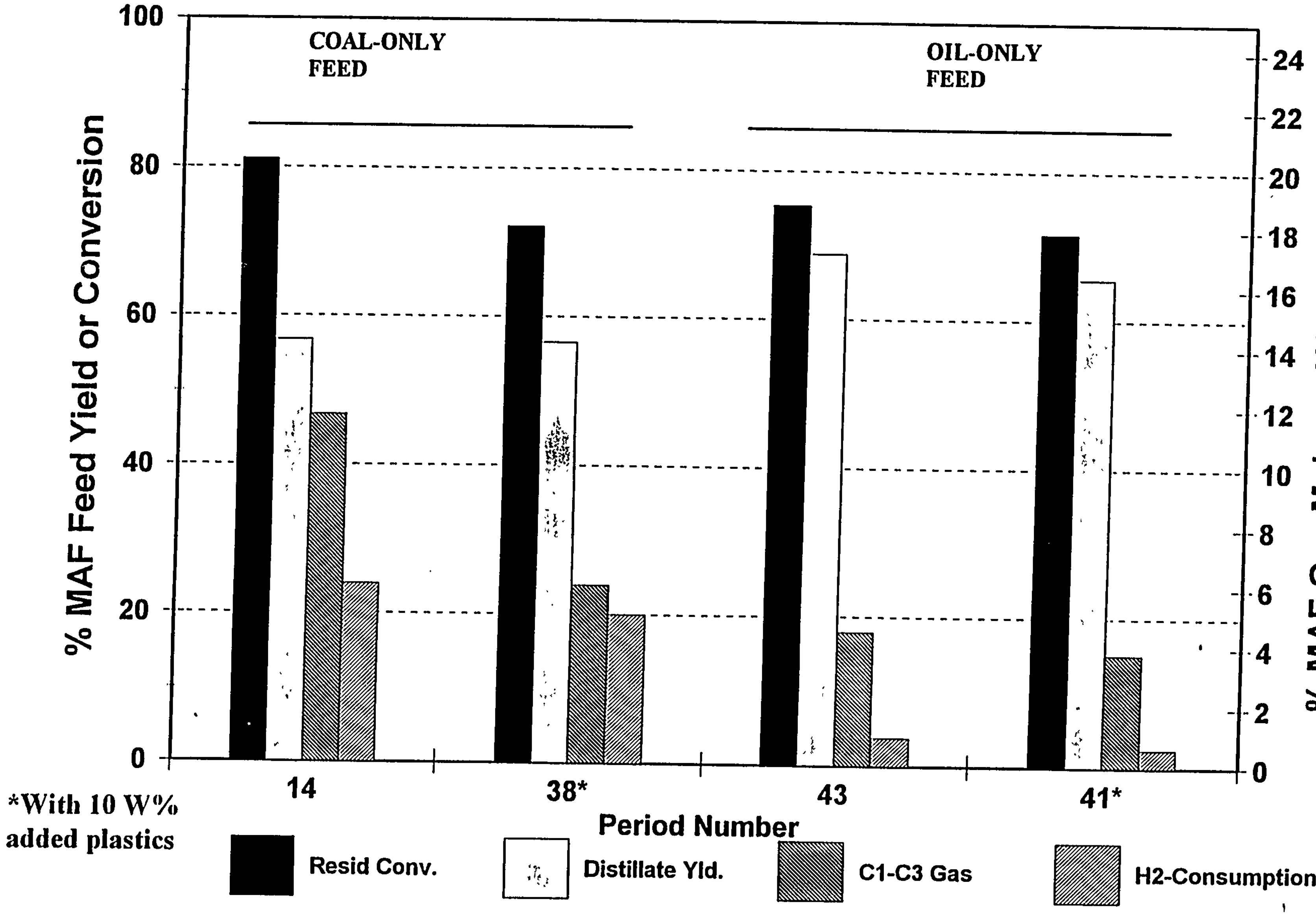
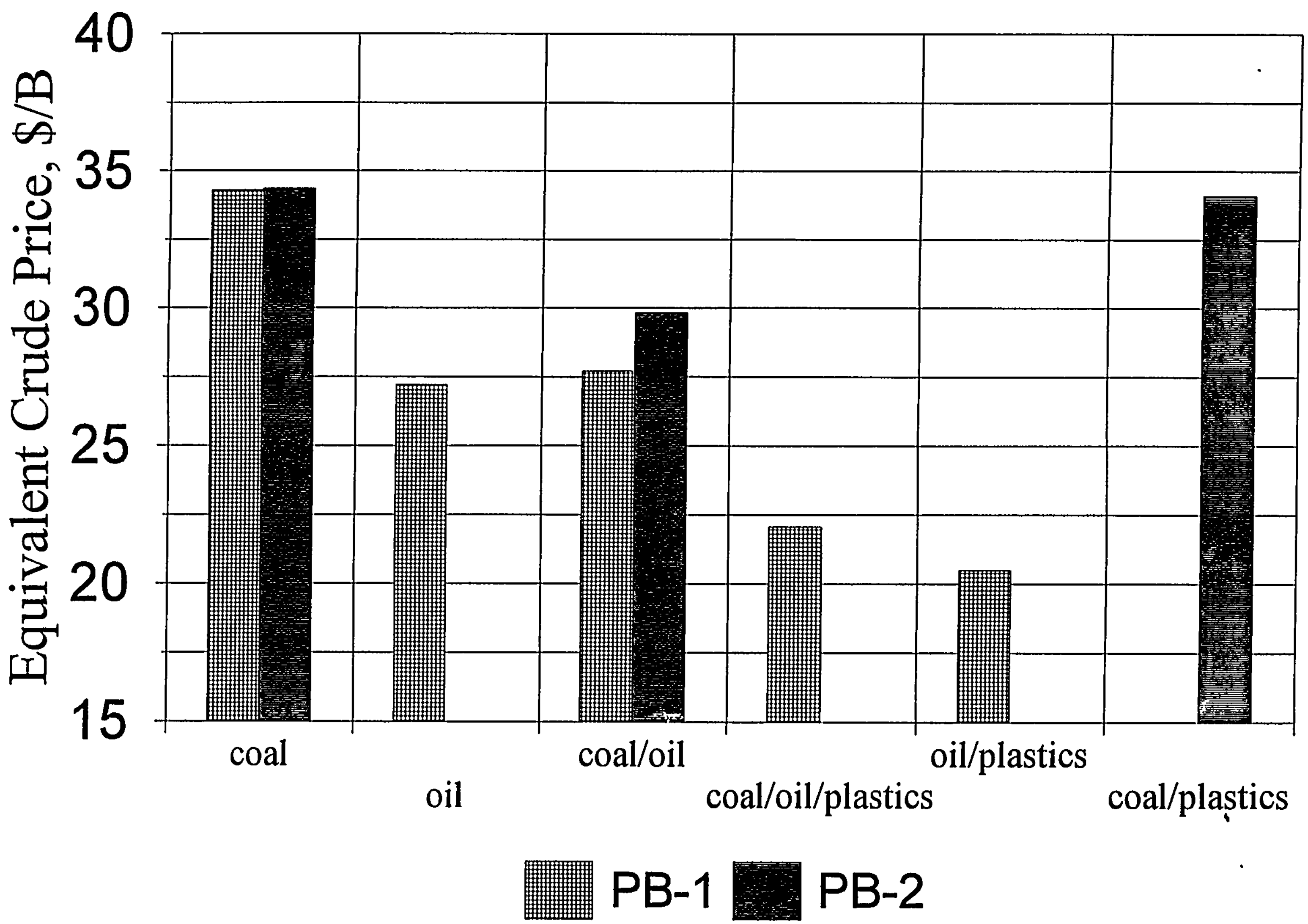


Figure 17. Comparison of Economic Results between PB-01 and PB-02



APPENDIX [Daily Material Recovery Balance Data]

The material balance summary and the analysis of product gas streams are listed in the appendix. The material balance summary lists all the input streams to the unit, including recycle, and all the output streams, along with the material recovery balance number (page 1). The temperatures of various fractionators and separators, and pressure filtration data are summarized on page 2. The hourlay feed, recycle, and product stream rates are summarized on page 3, while the yield of product stream, based upon W% moisture-free feed, are listed on page 4. The GC analyses of vent and bottom gases is summarized on page 5. The PFL fed to the buffer includes the PFL material pumped to the ebullating pump hot checks. The normalized yields of individual light gases is also included now in the appendix.

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RUN 227-91 (POC PB-02) MATERIAL BALANCE

Coal-Waste Coprocessing using Supported/Dispersed (Hybrid) Catalysts

FEED: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)
Hondo VTB Oil and Waste Plastics
CATALYSTS: HTI'S Fe (5000 ppm)+ MOLYVAN-A (50 ppm) to K-1
Akzo AO-60 NiMo/Alumina

'eriod Number	01T	02T	03T	04T	06T	07T	08T
'ate (Start of Period)	11/28/95	11/29/95	11/30/95	12/01/95	12/03/95	12/04/95	12/05/95
'uration, hrs	24.	24.	24.	24.	24.	24.	24.
ours of Run (End of Period)	24.	48.	72.	96.	24.	48.	72.
NPUTS, GRAMS							
Total Feed	31594.7	39008.0	40021.0	37803.0	12792.4	35421.0	41898.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	12580.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	49369.0	36660.0	37623.0	37817.0	18201.0	33666.0	41982.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	618.0	779.0	906.0	790.0	477.0	751.0	871.0
Pfl to Stage 2 Buffer	707.0	802.0	860.0	880.0	570.0	928.0	976.0
Water to Hot Separators	9300.0	10187.0	10074.0	9897.0	6305.0	9650.0	9924.0
Total Sulfur Added	2590.0	2590.0	2594.0	978.0	986.0	1986.0	1073.8
Additive (Fe+Mo Catalysts)	1039.0	876.0	895.0	921.0	448.0	924.0	1177.4
H2 to 1st Stage	4625.7	4625.5	4623.2	4625.0	4625.9	4628.2	4628.5
H2 to 2nd Stage	2024.2	2024.2	2024.2	2024.0	2023.8	2024.0	2112.2
Hydrogen Bleed	695.2	695.0	695.0	694.9	694.8	694.9	695.0
TOTAL GRAMS IN	102562.8	98246.8	100315.4	96429.9	59703.9	90673.1	105337.9
JTPUTS, GRAMS							
Hydrogen Out	5135.4	4557.7	4587.8	4502.9	5516.2	4634.2	4259.9
Total Gas Product (N2,H2 Free)	8579.5	8626.0	8537.9	10133.3	8236.7	8528.2	10987.3
Unit Knockouts	0.0	0.0	245.0	75.0	0.0	236.0	31.0
Separator Overhead (HTU) Product	23603.0	32264.0	33591.0	29707.0	11459.0	27071.0	34425.0
Atmospheric Overhead Product (Sample)	230.0	438.0	312.0	313.0	317.0	471.0	2329.0
CAS Bottoms	62396.0	47470.0	48150.0	46377.0	33415.0	44144.0	50711.0
Feed + Interstage Slurry Sample	0.0	172.0	83.0	107.0	0.0	298.0	0.0
TOTAL GRAMS OUT	99943.9	93527.8	95506.7	91215.2	58943.8	85382.4	102743.2
% Total Material Recovery (Gross)	97.45	95.20	95.21	94.59	98.73	94.17	97.54

: AGC TLKL RHS DLT WFK VRP JH

Period Number	01T	02T	03T	04T	06T	07T	08T
----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							
CAS Vapor Outlet Temperature, deg-f	463.	489.	488.	520.	492.	532.	545.
CAS Reboiler Temperature, deg-f	606.	614.	615.	616.	577.	611.	594.
CAS Charge	62626.0	47908.0	48462.0	46690.0	33732.0	44615.0	53040.0
CAS Overheads to HTU Feed Pot	230.0	438.0	312.0	313.0	317.0	471.0	2329.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	62396.0	47470.0	48150.0	46377.0	33415.0	44144.0	50711.0
PRESSURE FILTER							
Pressure Filter Charge, gms	62396.0	47470.0	48150.0	45136.0	33216.0	43472.0	50244.0
Pressure Filter Cake, gms	3810.0	6356.0	7085.0	7301.0	1605.0	5297.0	6382.0
Pressure Filter Liquid, gms	58005.0	40580.0	40665.0	37835.0	31511.0	38171.0	43578.0
Pressure Filter Loss, gms	581.0	534.0	400.0	0.0	100.0	4.0	284.0
W% Pfs	6.11	13.39	14.71	16.18	4.83	12.18	12.70

Period Number	01T	02T	03T	04T	06T	07T	08T
-----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	1316.4	1625.3	1667.5	1575.1	533.0	1475.9	1745.8
Dry Carbonaceous Feed	1184.8	1462.8	1500.8	1417.6	479.7	1328.3	1571.2
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	524.2	0.0	0.0
Water to Hot Separator	387.5	424.5	419.8	412.4	262.7	402.1	413.5
H2 to 1st Stage	192.7	192.7	192.6	192.7	192.7	192.8	192.9
H2 to 2nd Stage	84.3	84.3	84.3	84.3	84.3	84.3	88.0
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	2057.0	1527.5	1567.6	1575.7	758.4	1402.8	1749.3
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	25.8	32.5	37.8	32.9	19.9	31.3	36.3
Pfl to 2nd Stage Buffer	29.5	33.4	35.8	36.7	23.8	38.7	40.7
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	699.6	654.9	644.9	716.1	703.8	682.7	776.2
(N2 free)	571.5	549.3	546.9	609.8	573.0	548.4	635.3
SOH	496.4	575.8	614.8	614.4	191.3	483.4	638.5
SOH-H2O	487.1	768.5	784.9	623.4	286.1	644.5	795.8
SOH-NET WATER	99.6	344.1	365.1	211.0	23.4	242.5	382.3
Knockouts	0.0	0.0	10.2	3.1	0.0	9.8	1.3
Filter Cake	158.8	264.8	295.2	304.2	66.9	220.7	265.9
Filter Liquid	328.8	119.7	69.8	-68.8	515.1	117.9	1.4
Asoh + KO	9.6	18.3	23.2	16.2	13.2	29.5	98.3
Total CAS Bottoms	2599.8	1977.9	2006.3	1932.4	1392.3	1839.3	2113.0
Reactor 1 Liquid Sample	0.0	7.2	3.5	4.5	0.0	12.4	0.0
Separator Bottoms to CAS	2609.4	1996.2	2019.3	1945.4	1405.5	1859.0	2210.0
Total Asoh	9.6	18.3	23.2	16.2	13.2	29.5	98.3
CAS Bottoms to Pressure Filter	2599.8	1977.9	2006.3	1880.7	1384.0	1811.3	2093.5
Total Filter Cake	158.8	264.8	295.2	304.2	66.9	220.7	265.9
Total Filter Liquid	2441.1	1713.1	1711.0	1576.5	1317.1	1590.6	1827.6

Period number	01T	02T	03T	04T	06T	07T	08T
-----NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	7.35	5.32	4.98	5.78	14.44	5.00	6.99
Total C1-C3	9.42	8.19	8.07	10.17	19.68	9.36	10.02
Total C4-C7	3.55	3.41	3.32	4.79	8.43	3.76	3.74
SOH TOTAL H2O	41.11	52.54	52.30	43.98	59.64	48.52	50.65
SOH NET WATER	8.41	23.52	24.33	14.89	4.88	18.25	24.33
SOH Distillate Oil	41.90	39.36	40.96	43.34	39.88	36.39	40.64
Asoh + KO	0.81	1.25	1.55	1.14	2.75	2.22	6.26
Pfl	27.75	8.18	4.65	-1.80	109.03	10.73	1.17
Pfs	13.40	18.10	19.67	22.05	14.02	16.87	17.08
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.00	0.49	0.23	0.31	0.00	0.93	0.00
H2 Consumed--Meter, W% Dry Feed	7.8	7.9	7.6	8.4	15.9	8.5	8.4

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	1	2	3	4	6	7	8
CH4	2.81	2.43	2.11	2.43	5.27	2.44	2.62
C2H4	0.10	0.06	0.07	0.07	0.20	0.08	0.07
C2H6	2.00	1.79	1.79	2.13	3.44	1.80	2.01
C3H6	0.22	0.17	0.19	0.27	0.53	0.19	0.20
C3H8	1.74	1.90	2.12	2.82	3.46	1.99	2.12
C4H8	0.21	0.17	0.20	0.27	0.60	0.16	0.18
N-C4H10	0.93	0.93	1.08	1.63	1.97	0.99	1.09
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.42	0.37	0.36	0.53	1.03	0.49	0.37
I-C5H12	0.26	0.30	0.25	0.38	0.77	0.29	0.27
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.06	0.09	0.04	0.13	0.45	0.10	0.04
N-C6H14	0.00	0.04	0.09	0.18	0.15	0.05	0.08
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.80	0.65	0.74	0.90	1.95	0.85	1.03
CO2	6.47	4.63	4.19	4.80	12.33	4.09	5.86
H2S	3.90	3.34	3.53	5.02	11.90	3.64	3.96

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	1	2	3	4	6	7	8
CH4	0.89	0.58	0.52	0.82	2.72	0.97	1.07
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.72	0.51	0.50	0.70	1.81	0.80	0.89
C3H6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3H8	0.93	0.74	0.75	0.93	2.25	1.09	1.05
C4H8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C4H10	0.64	0.56	0.54	0.54	1.48	0.73	0.79
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.03	0.00	0.00	0.00
N-C5H12	0.35	0.30	0.30	0.19	0.72	0.36	0.32
I-C5H12	0.18	0.17	0.15	0.12	0.39	0.18	0.19
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.34	0.28	0.16	0.64	0.69	0.23	0.26
N-C6H14	0.13	0.14	0.10	0.08	0.16	0.12	0.13
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.01	0.00	0.00	0.00
CO2	0.08	0.04	0.05	0.06	0.16	0.06	0.10
H2S	5.95	4.32	3.80	4.03	17.09	4.99	4.42

30-APR-96 15:46

RUN 227-91 (POC PB-02) MATERIAL BALANCE

Coal-Waste Coprocessing using Supported/Dispersed (Hybrid) Catalysts

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FEED: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)
Hondo VTB Oil and Waste Plastics
CATALYSTS: HTI'S Fe (5000 ppm)+ MOLYVAN-A (50 ppm) to K-1
Akzo AO-60 NiMo/Alumina

eriod Number	09T	10T	11T	12T	13T	14T	15T
ate (Start of Period)	12/06/95	12/07/95	12/08/95	12/09/95	12/10/95	12/11/95	12/12/95
uration, hrs	24.	24.	24.	24.	24.	24.	24.
ours of Run (End of Period)	96.	120.	144.	168.	192.	216.	240.
NPUTS, GRAMS							
Total Feed	43968.0	41035.0	38473.0	41294.7	51280.0	46805.7	59297.7
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	43968.0	41155.0	37973.0	43270.0	50981.0	44761.0	15881.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	690.0	711.0	1065.0	1510.0	1562.0	4323.0	1369.0
Pfl to Stage 2 Buffer	850.0	794.0	1133.0	4410.0	1148.0	2246.0	1122.0
Water to Hot Separators	10012.0	9528.0	9655.0	9671.0	9721.0	10279.0	9472.0
Total Sulfur Added	1192.0	1192.0	1664.0	1865.5	4206.0	4206.0	4400.0
Additive (Fe+Mo Catalysts)	1116.0	1038.0	1289.3	1012.0	1297.0	1262.0	1460.0
H2 to 1st Stage	4628.7	4629.7	4629.7	4629.9	4630.1	4630.4	4630.1
H2 to 2nd Stage	2026.6	2026.5	2026.5	2026.7	2026.9	2027.0	2025.9
Hydrogen Bleed	694.9	694.8	694.8	694.9	695.2	695.3	695.2
TOTAL GRAMS IN	109146.2	102804.0	98603.4	110384.7	127547.1	121235.4	100352.8
TPUTS, GRAMS							
Hydrogen Out	4313.1	4181.4	4276.4	4272.0	4113.3	3874.1	4169.2
Total Gas Product (N2,H2 Free)	8630.8	11950.9	10792.9	8928.9	9119.1	13706.5	9054.2
Unit Knockouts	0.0	0.0	14.0	0.0	0.0	0.0	0.0
Separator Overhead (HTU) Product	38414.0	33926.0	32881.0	35968.0	35781.0	32500.0	29078.0
Atmospheric Overhead Product (Sample)	6022.0	581.0	0.0	485.0	242.0	0.0	0.0
CAS Bottoms	47219.0	50210.0	58649.0	63478.0	71801.0	67711.0	54068.0
Feed + Interstage Slurry Sample	0.0	0.0	0.0	0.0	0.0	269.0	104.0
TOTAL GRAMS OUT	104598.9	100849.3	106613.3	113131.8	121056.3	118060.6	96473.4
% Total Material Recovery (Gross)	95.83	98.10	108.12	102.49	94.91	97.38	96.13

': AGC TLKL RHS DLT WFK VRP JH

Period Number	09T	10T	11T	12T	13T	14T	15T
-----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							
CAS Vapor Outlet Temperature, deg-f	539.	516.	528.	532.	373.	237.	238.
CAS Reboiler Temperature, deg-f	594.	583.	601.	596.	460.	324.	324.
CAS Charge	53241.0	50791.0	58649.0	63963.0	72043.0	67711.0	54068.0
CAS Overheads to HTU Feed Pot	6022.0	581.0	0.0	485.0	242.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	47219.0	50210.0	58649.0	63478.0	71801.0	67711.0	54068.0
PRESSURE FILTER							
Pressure Filter Charge, gms	46548.0	49547.0	57456.0	62697.0	71324.0	67279.0	53635.0
Pressure Filter Cake, gms	7723.0	8561.0	7193.0	4152.0	5039.0	5187.0	7630.0
Pressure Filter Liquid, gms	38439.0	40686.0	48462.0	56974.0	66128.0	61918.0	45451.0
Pressure Filter Loss, gms	386.0	300.0	1801.0	1571.0	157.0	174.0	554.0
W% Pfs	16.59	17.28	12.52	6.62	7.06	7.71	14.23

eriod Number	09T	10T	11T	12T	13T	14T	15T
----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	1832.0	1709.8	1603.0	1720.6	2136.7	1950.2	2470.7
Dry Carbonaceous Feed	1648.8	1538.8	1442.7	1548.6	1923.0	1755.2	2223.7
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	417.2	397.0	402.3	403.0	405.0	428.3	394.7
H2 to 1st Stage	192.9	192.9	192.9	192.9	192.9	192.9	192.9
H2 to 2nd Stage	84.4	84.4	84.4	84.4	84.5	84.5	84.4
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	1832.0	1714.8	1582.2	1802.9	2124.2	1865.0	661.7
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	28.8	29.6	44.4	62.9	65.1	180.1	57.0
Pfl to 2nd Stage Buffer	35.4	33.1	47.2	183.8	47.8	93.6	46.8
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	660.3	815.5	761.6	695.6	696.1	871.4	660.9
(N2 free)	539.3	672.2	627.9	550.0	551.3	732.5	551.0
SOH	813.1	621.3	640.9	800.3	765.4	602.5	567.4
SOH-H2O	787.5	792.3	729.1	698.4	725.5	751.7	644.2
SOH-NET WATER	370.3	395.3	326.8	295.5	320.4	323.4	249.5
Knockouts	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Filter Cake	321.8	356.7	299.7	173.0	210.0	216.1	317.9
Filter Liquid	-278.5	-69.8	420.5	389.8	524.8	448.4	1151.4
Asoh + KO	250.9	24.2	0.6	20.2	10.1	0.0	0.0
Total CAS Bottoms	1967.5	2092.1	2443.7	2644.9	2991.7	2821.3	2252.8
Reactor 1 Liquid Sample	0.0	0.0	0.0	0.0	0.0	11.2	4.3
Separator Bottoms to CAS	2218.4	2116.3	2443.7	2665.1	3001.8	2821.3	2252.8
Total Asoh	250.9	24.2	0.6	20.2	10.1	0.0	0.0
CAS Bottoms to Pressure Filter	1939.5	2064.5	2394.0	2612.4	2971.8	2803.3	2234.8
Total Filter Cake	321.8	356.7	299.7	173.0	210.0	216.1	317.9
Total Filter Liquid	1617.7	1707.8	2094.3	2439.4	2761.9	2587.2	1916.9

Period number	09T	10T	11T	12T	13T	14T	15T
-----NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	6.02	8.11	6.36	5.32	3.77	4.74	2.10
Total C1-C3	7.99	11.82	10.21	9.26	7.19	11.23	5.49
Total C4-C7	2.79	5.15	4.74	3.42	2.54	8.15	4.34
SOH TOTAL H2O	47.76	51.49	50.54	45.10	37.73	42.82	28.97
SOH NET WATER	22.46	25.69	22.65	19.08	16.66	18.42	11.22
SOH Distillate Oil	49.31	40.37	44.42	51.68	39.80	34.33	25.52
Asoh + KO	15.22	1.57	0.04	1.30	0.52	0.00	0.00
Pfl	-15.47	-3.05	32.16	27.13	28.25	26.49	52.47
Pfs	19.80	23.49	21.20	11.31	10.99	12.39	14.41
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.00	0.00	0.00	0.00	0.00	0.64	0.19
H2 Consumed--Meter, W% Dry Feed	7.7	8.6	8.9	8.3	7.0	8.3	6.0

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	9	10	11	12	13	14	15
CH4	2.21	2.70	2.24	2.31	1.78	2.15	1.29
C2H4	0.06	0.08	0.09	0.07	0.06	0.19	0.03
C2H6	1.66	2.65	2.11	1.85	1.41	2.53	1.01
C3H6	0.13	0.27	0.32	0.21	0.14	0.26	0.12
C3H8	1.62	3.55	2.68	2.10	1.50	3.17	1.19
C4H8	0.10	0.27	0.27	0.19	0.11	0.30	0.20
N-C4H10	0.78	2.04	1.81	1.18	0.79	1.14	0.34
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.36	0.15
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.26	0.60	0.58	0.39	0.25	0.45	0.19
I-C5H12	0.16	0.42	0.35	0.25	0.16	0.27	0.12
METHYL-CYCLOPENTANE	0.00	0.21	0.05	0.00	0.00	0.81	0.49
CYCLOHEXANE	0.04	0.00	0.23	0.08	0.10	0.84	0.55
N-C6H14	0.08	0.00	0.09	0.09	0.03	0.61	0.34
C6-C7	0.00	0.08	0.00	0.00	0.00	0.00	0.00
CO	0.87	0.96	0.90	1.08	0.92	1.17	0.67
CO2	5.09	7.05	5.25	4.01	2.69	3.37	1.33
H2S	1.55	3.60	6.87	3.12	3.60	5.62	2.88

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	9	10	11	12	13	14	15
CH4	0.82	0.90	1.16	1.13	0.86	1.10	0.70
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.67	0.74	0.76	0.75	0.64	0.80	0.51
C3H6	0.00	0.00	0.00	0.00	0.00	0.01	0.00
C3H8	0.82	0.94	0.86	0.84	0.78	1.02	0.64
C4H8	0.00	0.00	0.00	0.00	0.00	0.01	0.02
N-C4H10	0.55	0.58	0.54	0.51	0.47	0.36	0.21
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.10	0.07
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.24	0.24	0.27	0.22	0.20	0.23	0.18
I-C5H12	0.13	0.15	0.13	0.12	0.10	0.11	0.09
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.34	0.21
CYCLOHEXANE	0.29	0.39	0.26	0.27	0.19	0.70	0.36
N-C6H14	0.10	0.13	0.11	0.10	0.11	0.27	0.16
C6-C7	0.00	0.00	0.00	0.00	0.00	0.51	0.25
O	0.01	0.02	0.03	0.03	0.02	0.05	0.03
O2	0.06	0.08	0.18	0.20	0.14	0.15	0.07
2S	3.45	3.67	3.00	2.91	2.66	2.81	2.15

0-APR-96 15:47

RUN 227-91 (POC PB-02) MATERIAL BALANCE

Coal-Waste Coprocessing using Supported/Dispersed (Hybrid) Catalysts

FEED: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)
Hondo VTB Oil and Waste Plastics
CATALYSTS: HTI'S Fe (5000 ppm)+ MOLYVAN-A (50 ppm) to K-1
Akzo AO-60 NiMo/Alumina

eriod Number	16T	17T	18T	19T	20T	21T	22T
ate (Start of Period)	12/13/95	12/14/95	12/15/95	12/16/95	12/17/95	12/18/95	12/19/95
uration, hrs	24.	24.	24.	24.	24.	24.	24.
ours of Run (End of Period)	264.	288.	312.	336.	360.	384.	408.
NPUTS, GRAMS							
Total Feed	43968.0	43968.0	43301.0	45652.0	48807.0	51016.0	52756.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	7488.0	7488.0	7375.0	6608.0	6816.0	7124.0	7368.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	1401.0	1273.0	1334.0	914.0	1089.0	1152.0	1424.0
Pfl to Stage 2 Buffer	1073.0	1000.0	991.0	1050.0	845.0	1004.0	1115.0
Water to Hot Separators	9738.0	9691.0	10152.0	9804.0	9700.0	9632.0	9509.0
Total Sulfur Added	4406.0	4408.0	1200.0	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	1112.0	1112.0	1095.0	980.0	1011.0	1057.0	1093.0
H2 to 1st Stage	4628.5	4628.2	4628.0	4628.0	4628.1	4628.1	4628.2
H2 to 2nd Stage	2025.7	2025.7	2025.3	2025.4	2025.4	2025.5	2020.3
Hydrogen Bleed	695.0	695.0	694.8	694.8	694.9	695.0	695.1
TOTAL GRAMS IN	76535.3	76288.9	72796.1	73556.2	76816.4	79533.6	81808.5
JTPUTS, GRAMS							
Hydrogen Out	4593.3	4929.2	4842.9	5071.5	5335.1	5503.0	5530.3
Total Gas Product (N2,H2 Free)	8670.4	7411.2	7029.9	7080.8	7991.2	7087.2	7097.7
Unit Knockouts	0.0	0.0	0.0	10.0	8.0	7.0	0.0
Separator Overhead (HTU) Product	25799.0	24917.0	28037.0	23784.0	22997.0	22861.0	25233.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAS Bottoms	31957.0	33903.0	35354.0	38813.0	39977.0	42285.0	42099.0
Feed + Interstage Slurry Sample	239.0	0.0	454.0	180.0	217.0	151.0	397.0
TOTAL GRAMS OUT	71258.6	71160.3	75717.8	74939.4	76525.4	77894.2	80357.0
% Total Material Recovery (Gross)	93.11	93.28	104.01	101.88	99.62	97.94	98.23

: AGC TLKL RHS DLT WFK VRP JH

Period Number	16T	17T	18T	19T	20T	21T	22T
-----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							
CAS Vapor Outlet Temperature, deg-f	239.	241.	243.	242.	240.	240.	238.
CAS Reboiler Temperature, deg-f	325.	325.	326.	326.	326.	325.	324.
CAS Charge	31957.0	33903.0	35354.0	38813.0	39977.0	42285.0	42099.0
CAS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	31957.0	33903.0	35354.0	38813.0	39977.0	42285.0	42099.0
PRESSURE FILTER							
Pressure Filter Charge, gms	31499.0	33417.0	34468.0	38667.0	39732.0	41905.0	41697.0
Pressure Filter Cake, gms	7174.0	6181.0	5622.0	4950.0	1920.0	920.0	2017.0
Pressure Filter Liquid, gms	24181.0	27072.0	28590.0	30433.0	35909.0	39436.0	39599.2
Pressure Filter Loss, gms	144.0	164.0	256.0	3284.0	1903.0	1549.0	80.8
W% Pfs	22.78	18.50	16.31	12.80	4.83	2.20	4.84

eriod Number	16T	17T	18T	19T	20T	21T	22T
----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	1832.0	1832.0	1804.2	1902.2	2033.6	2125.7	2198.2
Dry Carbonaceous Feed	1648.8	1648.8	1714.0	1712.0	1830.3	1913.1	2198.2
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	405.8	403.8	423.0	408.5	404.2	401.3	396.2
H2 to 1st Stage	192.9	192.8	192.8	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.4	84.4	84.4	84.4	84.4	84.4	84.2
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	312.0	312.0	307.3	275.3	284.0	296.8	307.0
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	58.4	53.0	55.6	38.1	45.4	48.0	59.3
Pfl to 2nd Stage Buffer	44.7	41.7	41.3	43.8	35.2	41.8	46.5
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	683.3	638.3	598.0	621.8	667.9	642.9	641.5
(N2 free)	552.7	514.2	494.7	506.3	555.3	524.6	526.2
SOH	498.0	380.1	587.5	448.8	486.1	496.8	616.0
SOH-H2O	576.9	658.1	580.7	542.2	472.1	455.7	435.4
SOH-NET WATER	171.2	254.3	157.7	133.7	68.0	54.4	39.2
Knockouts	0.0	0.0	0.0	0.4	0.3	0.3	0.0
Filter Cake	298.9	257.5	234.3	206.3	80.0	38.3	84.0
Filter Liquid	598.5	728.1	797.8	1047.7	1210.9	1321.0	1240.5
Asoh + KO	0.0	0.0	0.0	0.4	0.3	0.3	0.0
Total CAS Bottoms	1331.5	1412.6	1473.1	1617.2	1665.7	1761.9	1754.1
Reactor 1 Liquid Sample	10.0	0.0	18.9	7.5	9.0	6.3	16.5
Separator Bottoms to CAS	1331.5	1412.6	1473.1	1617.2	1665.7	1761.9	1754.1
Total Asoh	0.0	0.0	0.0	0.4	0.3	0.3	0.0
CAS Bottoms to Pressure Filter	1312.5	1392.4	1436.2	1611.1	1655.5	1746.0	1737.4
Total Filter Cake	298.9	257.5	234.3	206.3	80.0	38.3	84.0
Total Filter Liquid	1013.5	1134.8	1201.9	1404.9	1575.5	1707.7	1653.3

Period number	16T	17T	18T	19T	20T	21T	22T
-----NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	2.24	2.22	2.06	0.66	0.17	0.13	0.06
Total C1-C3	7.16	7.52	6.76	5.91	5.66	5.05	4.34
Total C4-C7	8.02	3.41	3.16	3.33	3.84	2.89	2.55
SOH TOTAL H2O	34.99	39.92	33.88	31.67	25.80	23.82	19.81
SOH NET WATER	10.38	15.43	9.20	7.81	3.71	2.84	1.78
SOH Distillate Oil	30.21	23.05	34.28	26.22	26.56	25.97	28.02
Asoh + KO	0.00	0.00	0.00	0.02	0.02	0.02	0.00
Pfl	37.19	45.16	48.35	61.51	66.69	69.86	57.16
Pfs	18.39	15.85	14.02	12.09	4.40	2.02	3.86
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.60	0.00	1.10	0.44	0.49	0.33	0.75
H2 Consumed--Meter, W% Dry Feed	7.0	6.1	6.1	5.5	4.6	4.0	3.4

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	16	17	18	19	20	21	22
CH4	1.59	1.83	1.72	1.30	1.20	1.21	1.07
C2H4	0.26	0.07	0.06	0.07	0.07	0.06	0.06
C2H6	1.44	1.46	1.37	1.14	1.12	0.92	0.86
C3H6	0.20	0.20	0.19	0.26	0.30	0.21	0.22
C3H8	1.57	1.76	1.54	1.49	1.41	1.06	0.92
C4H8	0.29	0.19	0.18	0.27	0.35	0.26	0.25
N-C4H10	0.57	0.85	0.77	0.87	0.89	0.59	0.56
I-C4H10	0.22	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.30	0.39	0.36	0.35	0.45	0.40	0.41
I-C5H12	0.20	0.25	0.23	0.31	0.38	0.27	0.26
METHYL-CYCLOPENTANE	0.75	0.00	0.00	0.00	0.08	0.00	0.00
CYCLOHEXANE	0.79	0.04	0.15	0.04	0.04	0.00	0.03
N-C6H14	0.52	0.08	0.08	0.08	0.16	0.04	0.03
C6-C7	0.72	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.72	0.71	0.68	0.31	0.09	0.08	0.05
CO2	1.46	1.46	1.33	0.32	0.06	0.04	0.02
H2S	1.88	2.52	2.36	3.68	4.47	3.24	3.06

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	16	17	18	19	20	21	22
CH4	0.75	0.84	0.71	0.50	0.47	0.48	0.38
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.59	0.62	0.55	0.49	0.46	0.46	0.36
C3H6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C3H8	0.77	0.74	0.63	0.66	0.63	0.64	0.48
C4H8	0.01	0.00	0.00	0.00	0.00	0.00	0.00
N-C4H10	0.26	0.46	0.37	0.43	0.42	0.47	0.36
I-C4H10	0.10	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.27	0.35	0.27	0.28	0.29	0.34	0.25
I-C5H12	0.14	0.18	0.13	0.19	0.23	0.26	0.20
METHYL-CYCLOPENTANE	0.41	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.69	0.25	0.26	0.13	0.07	0.05	0.02
N-C6H14	0.34	0.20	0.20	0.20	0.18	0.09	0.08
C6-C7	0.49	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.02	0.02	0.00	0.00	0.00	0.00	0.00
CO2	0.04	0.03	0.05	0.03	0.01	0.01	0.00
H2S	2.61	3.06	2.75	3.65	4.06	4.13	3.44

10-APR-96 15:58

RUN 227-91 (POC PB-02) MATERIAL BALANCE

Coal-Waste Coprocessing using Supported/Dispersed (Hybrid) Catalysts

FEED: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)
Hondo VTB Oil and Waste Plastics
CATALYSTS: HTI'S Fe (5000 ppm)+ MOLYVAN-A (50 ppm) to K-1
Akzo AO-60 NiMo/Alumina

eriod Number	23T	24T	25T	26T	27T	28T	29T
ate (Start of Period)	12/20/95	12/21/95	12/22/95	12/23/95	12/24/95	12/25/95	12/26/95
uration, hrs	24.	24.	24.	24.	24.	24.	24.
ours of Run (End of Period)	432.	456.	480.	504.	528.	552.	576.
NPUTS, GRAMS							
Total Feed	49382.0	51646.0	50940.0	53308.1	53847.0	52377.0	52359.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	6944.0	7213.0	6976.0	7445.0	7520.0	7315.0	7312.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	974.0	1091.0	685.0	1313.0	846.0	774.0	906.0
Pfl to Stage 2 Buffer	2373.0	737.0	5087.0	1109.0	726.0	824.0	799.0
Water to Hot Separators	9567.0	9874.0	9319.0	9325.0	9847.0	9930.0	10157.0
Total Sulfur Added	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	1023.0	1070.0	1055.0	1105.0	1074.0	1086.0	1085.0
H2 to 1st Stage	4628.3	4626.6	4626.1	4626.4	4626.5	4626.8	4627.0
H2 to 2nd Stage	2024.7	2025.5	2025.4	2026.0	2026.0	2026.1	2026.1
Hydrogen Bleed	695.1	695.1	694.9	694.8	694.8	694.9	694.9
TOTAL GRAMS IN	78811.1	80178.2	82608.4	82152.3	82407.4	80853.7	81165.9
TPUTS, GRAMS							
Hydrogen Out	5479.4	5615.1	5285.5	5503.0	5529.2	5510.9	5542.2
Total Gas Product (N2,H2 Free)	7774.9	9560.1	7594.7	6494.7	7245.4	7994.2	7159.7
Unit Knockouts	0.0	19.0	0.0	12.0	0.0	0.0	0.0
Separator Overhead (HTU) Product	26015.0	24766.0	24084.0	24860.0	25392.0	25336.0	24392.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAS Bottoms	41676.0	43063.0	45861.0	45667.0	44508.0	45095.0	43463.0
Feed + Interstage Slurry Sample	155.0	139.0	98.0	537.0	130.0	108.0	134.0
TOTAL GRAMS OUT	81100.3	83162.3	82923.3	83073.7	82804.6	84044.1	80690.9
% Total Material Recovery (Gross)	102.90	103.72	100.38	101.12	100.48	103.95	99.41

: AGC TLKL RHS DLT WFK VRP JH

* 227 UNIT MATERIAL BALANCE (CON'T) * PAGE 2

Period Number	23T	24T	25T	26T	27T	28T	29T
----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							

CAS Vapor Outlet Temperature, deg-f	236.	238.	240.	240.	240.	240.	238.
CAS Reboiler Temperature, deg-f	324.	324.	325.	325.	325.	325.	325.
CAS Charge	41676.0	43063.0	45861.0	45667.0	44508.0	45095.0	43463.0
CAS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	41676.0	43063.0	45861.0	45667.0	44508.0	45095.0	43463.0
PRESSURE FILTER							

Pressure Filter Charge, gms	41083.0	42558.0	45448.0	44931.0	43987.0	44683.0	42984.0
Pressure Filter Cake, gms	579.0	707.0	875.0	721.0	858.0	911.0	1032.0
Pressure Filter Liquid, gms	38055.0	40041.0	42979.0	41917.0	40710.0	41654.0	39830.0
Pressure Filter Loss, gms	2449.0	1810.0	1594.0	2293.0	2419.0	2118.0	2122.0
Wt Pfs	1.41	1.66	1.93	1.60	1.95	2.04	2.40

Period Number	23T	24T	25T	26T	27T	28T	29T
----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	2057.6	2151.9	2122.5	2221.2	2243.6	2182.4	2181.6
Dry Carbonaceous Feed	1851.8	1936.7	1910.3	2221.2	2019.3	1964.1	1963.5
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	398.6	411.4	388.3	388.5	410.3	413.8	423.2
H2 to 1st Stage	192.8	192.8	192.8	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.4	84.4	84.4	84.4	84.4	84.4	84.4
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	289.3	300.5	290.7	310.2	313.3	304.8	304.7
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	40.6	45.5	28.5	54.7	35.3	32.3	37.8
Pfl to 2nd Stage Buffer	98.9	30.7	212.0	46.2	30.3	34.3	33.3
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	667.9	747.2	626.4	590.8	633.8	669.6	644.2
(N2 free)	552.3	632.3	536.7	499.9	532.3	562.7	529.2
SOH	650.0	575.3	565.3	589.9	594.9	580.0	545.5
SOH-H2O	434.0	456.7	438.2	445.9	463.1	475.7	470.9
SOH-NET WATER	35.3	45.3	49.9	57.4	52.8	61.9	47.7
Knockouts	0.0	0.8	0.0	0.5	0.0	0.0	0.0
Filter Cake	24.1	29.5	36.5	30.0	35.8	38.0	43.0
Filter Liquid	1258.9	1367.1	1326.0	1431.0	1418.2	1452.5	1372.3
Asoh + KO	0.0	0.8	0.0	0.5	0.0	0.0	0.0
Total CAS Bottoms	1736.5	1794.3	1910.9	1902.8	1854.5	1879.0	1811.0
Reactor 1 Liquid Sample	6.5	5.8	4.1	22.4	5.4	4.5	5.6
Separator Bottoms to CAS	1736.5	1794.3	1910.9	1902.8	1854.5	1879.0	1811.0
Total Asoh	0.0	0.8	0.0	0.5	0.0	0.0	0.0
CAS Bottoms to Pressure Filter	1711.8	1773.3	1893.7	1872.1	1832.8	1861.8	1791.0
Total Filter Cake	24.1	29.5	36.5	30.0	35.8	38.0	43.0
Total Filter Liquid	1687.7	1743.8	1857.2	1842.1	1797.0	1823.8	1748.0

* 227 UNIT MATERIAL BALANCE (CON'T) * PAGE 4

Period number	23T	24T	25T	26T	27T	28T	29T
-----NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	0.06	0.09	0.07	0.07	0.17	0.24	0.18
Total C1-C3	5.61	6.49	5.53	3.84	4.66	5.44	4.79
Total C4-C7	3.28	4.44	3.05	2.40	2.80	3.12	2.92
SOH TOTAL H2O	23.43	23.58	22.94	20.08	22.93	24.22	23.98
SOH NET WATER	1.91	2.34	2.61	2.58	2.61	3.15	2.43
SOH Distillate Oil	35.10	29.70	29.59	26.56	29.46	29.53	27.78
Asoh + KO	0.00	0.04	0.00	0.02	0.00	0.00	0.00
Pfl	69.30	71.66	70.30	65.78	71.29	74.81	70.88
Pfs	1.32	1.54	1.93	1.37	1.79	1.95	2.21
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.35	0.30	0.21	1.01	0.27	0.23	0.28
H2 Consumed--Meter, W% Dry Feed	4.2	3.7	4.5	3.5	3.8	3.9	3.8

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	23	24	25	26	27	28	29
CH4	1.09	1.20	1.15	1.02	1.05	1.10	1.01
C2H4	0.05	0.05	0.05	0.04	0.05	0.05	0.04
C2H6	1.00	1.21	0.99	0.78	0.79	0.97	0.78
C3H6	0.27	0.35	0.26	0.18	0.17	0.25	0.18
C3H8	1.36	1.71	1.31	0.46	0.83	1.21	0.92
C4H8	0.30	0.47	0.32	0.27	0.20	0.31	0.22
N-C4H10	0.80	1.08	0.77	0.46	0.49	0.72	0.52
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.35	0.64	0.48	0.35	0.32	0.40	0.34
I-C5H12	0.32	0.60	0.32	0.32	0.20	0.31	0.22
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.00	0.00	0.00	0.03	0.00	0.00	0.00
N-C6H14	0.04	0.04	0.08	0.03	0.03	0.04	0.04
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.04	0.05	0.04	0.04	0.11	0.14	0.12
CO2	0.02	0.02	0.02	0.02	0.05	0.09	0.06
H2S	4.51	5.48	4.25	2.62	2.37	3.39	2.51

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	23	24	25	26	27	28	29
CH4	0.60	0.61	0.62	0.46	0.59	0.60	0.56
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.56	0.58	0.54	0.41	0.56	0.55	0.55
C3H6	0.00	0.01	0.00	0.00	0.01	0.00	0.00
C3H8	0.68	0.76	0.61	0.48	0.61	0.70	0.75
C4H8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C4H10	0.46	0.52	0.40	0.35	0.50	0.46	0.51
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.29	0.32	0.22	0.19	0.35	0.27	0.33
I-C5H12	0.24	0.26	0.19	0.19	0.27	0.22	0.25
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.12	0.05	0.03	0.01	0.02	0.04	0.10
N-C6H14	0.16	0.17	0.07	0.06	0.18	0.14	0.18
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0.00	0.01	0.01	0.01	0.00	0.00	0.00
H2S	4.02	4.07	3.67	3.25	4.96	4.77	4.79

* 227 UNIT MATERIAL BALANCE (CON'T) * PAGE 2

Period Number	30T	31T	32T	33T	34T	35T	36T
-----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							
CAS Vapor Outlet Temperature, deg-f	239.	240.	240.	241.	242.	241.	239.
CAS Reboiler Temperature, deg-f	325.	325.	325.	325.	326.	325.	325.
CAS Charge	40669.0	40235.0	37874.0	34534.0	31300.0	46663.0	65843.0
CAS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	40669.0	40235.0	37874.0	34534.0	31300.0	46663.0	65843.0
PRESSURE FILTER							
Pressure Filter Charge, gms	39841.0	39841.0	37511.0	32976.0	30504.0	46684.0	65391.0
Pressure Filter Cake, gms	906.0	1578.0	3941.0	3772.0	3945.0	6632.0	8713.0
Pressure Filter Liquid, gms	36828.0	36286.0	30825.0	27001.0	24192.0	37261.0	53102.0
Pressure Filter Loss, gms	2107.0	1977.0	2745.0	2203.0	2367.0	2791.0	3576.0
W% Pfs	2.27	3.96	10.51	11.44	12.93	14.21	13.32

eriod Number	30T	31T	32T	33T	34T	35T	36T
----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	2124.1	2041.9	1947.3	1838.3	1669.9	1330.9	1778.0
Dry Carbonaceous Feed	2113.5	1837.7	1752.5	1654.5	1586.4	1197.8	1600.2
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	382.6	426.1	437.4	428.8	407.1	411.8	407.0
H2 to 1st Stage	192.8	192.8	192.8	192.8	192.8	192.8	192.4
H2 to 2nd Stage	84.4	84.4	84.4	84.4	84.4	84.4	84.4
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	300.0	334.2	331.6	313.1	372.8	1341.3	1867.7
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	36.9	34.7	32.9	36.3	36.5	43.8	50.0
Pfl to 2nd Stage Buffer	35.7	36.8	30.5	37.9	36.2	38.6	39.4
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	656.3	652.7	612.7	637.3	587.4	744.1	584.9
(N2 free)	541.2	524.1	496.3	525.2	472.3	629.1	526.0
SOH	536.5	515.8	510.8	481.1	488.9	502.8	602.5
SOH-H2O	459.9	516.0	595.6	590.1	566.7	624.3	622.5
SOH-NET WATER	77.3	89.9	158.3	161.3	159.5	212.5	215.6
Knockouts	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake	37.8	65.8	164.2	157.2	164.4	276.3	363.0
Filter Liquid	1249.7	1188.6	1003.8	829.6	661.1	245.2	404.4
Asoh + KO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total CAS Bottoms	1694.5	1676.5	1578.1	1438.9	1304.2	1944.3	2743.5
Reactor 1 Liquid Sample	20.6	4.0	2.0	4.3	13.6	4.3	2.3
Separator Bottoms to CAS	1694.5	1676.5	1578.1	1438.9	1304.2	1944.3	2743.5
Total Asoh	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAS Bottoms to Pressure Filter	1660.0	1660.0	1563.0	1374.0	1271.0	1945.2	2724.6
Total Filter Cake	37.8	65.8	164.2	157.2	164.4	276.3	363.0
Total Filter Liquid	1622.3	1594.3	1398.8	1216.8	1106.6	1668.8	2361.6

eriod number	30T	31T	32T	33T	34T	35T	36T
----NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	0.17	1.24	1.80	1.97	1.90	5.16	3.52
Total C1-C3	4.65	5.66	5.89	7.11	6.28	12.02	7.11
Total C4-C7	2.95	2.84	2.91	3.52	2.86	5.66	2.57
SOH TOTAL H2O	21.76	28.08	33.99	35.67	35.72	52.12	38.90
SOH NET WATER	3.66	4.89	9.03	9.75	10.06	17.74	13.47
SOH Distillate Oil	25.38	28.07	29.15	29.08	30.82	41.97	37.65
Asoh + KO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pfl	60.72	65.54	58.05	53.62	43.49	20.41	26.29
Pfs	1.82	3.61	9.46	9.95	10.63	23.06	22.84
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.98	0.22	0.11	0.26	0.86	0.36	0.15
H2 Consumed--Meter, W% Dry Feed	3.5	4.7	5.7	6.0	6.2	9.7	6.7

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	30	31	32	33	34	35	36
CH4	0.99	1.40	1.33	1.52	1.44	2.66	1.59
C2H4	0.05	0.05	0.06	0.06	0.05	0.08	0.05
C2H6	0.76	1.06	1.14	1.32	1.15	2.38	1.26
C3H6	0.17	0.15	0.18	0.21	0.16	0.33	0.15
C3H8	0.96	0.96	0.97	1.55	1.25	2.70	1.34
C4H8	0.25	0.17	0.19	0.23	0.19	0.37	0.15
N-C4H10	0.51	0.56	0.64	0.82	0.60	1.38	0.49
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.35	0.25	0.28	0.40	0.38	0.64	0.29
I-C5H12	0.29	0.19	0.21	0.26	0.20	0.47	0.13
METHYL-CYCLOPENTANE	0.03	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.00	0.11	0.00	0.23	0.08	0.05	0.04
N-C6H14	0.03	0.07	0.07	0.08	0.08	0.15	0.08
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.11	0.56	0.57	0.69	0.72	1.40	1.01
CO2	0.05	0.67	1.20	1.23	1.14	3.64	2.34
H2S	2.41	2.20	1.88	2.07	1.64	7.34	3.24

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	30	31	32	33	34	35	36
CH4	0.52	0.69	0.75	0.77	0.77	1.25	1.01
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.51	0.60	0.64	0.72	0.65	1.13	0.79
C3H6	0.00	0.01	0.00	0.00	0.00	0.01	0.00
C3H8	0.69	0.75	0.82	0.96	0.80	1.47	0.91
C4H8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C4H10	0.48	0.51	0.53	0.60	0.52	0.95	0.54
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.31	0.30	0.34	0.28	0.25	0.52	0.36
I-C5H12	0.23	0.23	0.23	0.20	0.17	0.30	0.19
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOHEXANE	0.09	0.10	0.10	0.13	0.20	0.32	0.20
N-C6H14	0.17	0.17	0.17	0.18	0.11	0.27	0.09
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.00	0.00	0.01	0.01	0.01	0.05	0.06
CO2	0.00	0.01	0.02	0.03	0.02	0.08	0.10
H2S	4.45	4.57	4.05	4.61	4.02	6.46	4.02

RUN 227-91 (POC PB-02) MATERIAL BALANCE

Coal-Waste Coprocessing using Supported/Dispersed (Hybrid) Catalysts

FEED: BLACK THUNDER MINE: POC-02 COAL (HRI-6213)
Hondo VTB Oil and Waste Plastics
CATALYSTS: HTI'S Fe (5000 ppm)+ MOLYVAN-A (50 ppm) to K-1
Akzo AO-60 NiMo/Alumina

ɛriod Number	37T	38T	39T	40T	41T	42T	43T
ɪate (Start of Period)	01/03/96	01/04/96	01/05/96	01/06/96	01/07/96	01/08/96	01/09/96
ɪration, hrs	24.	24.	24.	24.	24.	24.	24.
ɔurs of Run (End of Period)	768.	792.	816.	840.	864.	888.	912.
IPUTS, GRAMS							
Total Feed	43532.0	43444.0	54234.0	56368.0	54077.0	56583.0	57852.0
Makeup Oil to Charge (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makeup Oil to Buffer (L-814/extracted oil)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl Recycled to Charge+K-2 Cat Addition	45236.0	42686.0	16269.0	7865.0	7552.0	7902.0	8080.0
CAS Btms Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake Recycled to Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to Stage 1 Buffer	1082.0	1432.0	1067.0	1095.0	3363.0	911.0	935.0
Pfl to Stage 2 Buffer	837.0	928.0	1493.0	958.0	1646.0	901.0	886.0
Water to Hot Separators	10010.0	9917.0	9972.0	9103.0	9947.0	9807.0	9910.0
Total Sulfur Added	2328.4	2322.0	2223.4	1200.0	1200.0	1200.0	1200.0
Additive (Fe+Mo Catalysts)	1098.0	1083.0	1163.0	1167.0	1120.0	1172.0	1199.0
H2 to 1st Stage	4627.6	4590.6	4597.9	4628.3	4628.3	4628.3	4628.2
H2 to 2nd Stage	2026.6	2026.7	2026.5	2026.9	2027.0	2024.9	2026.5
Hydrogen Bleed	695.0	695.1	695.0	695.1	695.0	694.9	694.6
TOTAL GRAMS IN	111472.7	109124.4	93740.8	85106.3	86255.2	85824.1	87411.3
TPUTS, GRAMS							
Hydrogen Out	4772.7	4801.4	5036.0	5400.9	5760.7	5777.5	5478.5
Total Gas Product (N2,H2 Free)	8437.8	7249.1	7446.7	6601.9	6605.4	7894.2	8367.3
Unit Knockouts	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Separator Overhead (HTU) Product	28185.0	24766.0	23302.0	21877.0	22650.0	23355.0	24048.0
Atmospheric Overhead Product (Sample)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAS Bottoms	69166.0	71671.0	61956.0	51698.0	49673.0	49626.0	47716.0
Feed + Interstage Slurry Sample	0.0	350.0	69.0	60.0	343.0	99.0	419.0
TOTAL GRAMS OUT	110561.5	108837.5	97809.7	85637.8	85032.1	86751.6	86028.9
% Total Material Recovery (Gross)	99.18	99.74	104.34	100.62	98.58	101.08	98.42

: AGC TLKL RHS DLT WFK VRP JH

Period Number	37T	38T	39T	40T	41T	42T	43T
-----SEPARATOR BOTTOMS PRODUCT BREAKDOWN, GRAMS-----							
ATMOSPHERIC STILL							

CAS Vapor Outlet Temperature, deg-f	238.	237.	237.	237.	236.	237.	239.
CAS Reboiler Temperature, deg-f	325.	324.	324.	324.	324.	324.	324.
CAS Charge	69166.0	71671.0	61956.0	51698.0	49673.0	49626.0	47716.0
CAS Overheads to HTU Feed Pot	0.0	0.0	0.0	0.0	0.0	0.0	0.0
****ASOH AND UNIT KNOCKOUTS ARE BEING FED TO THE HTU*****							
CAS Bottoms	69166.0	71671.0	61956.0	51698.0	49673.0	49626.0	47716.0
PRESSURE FILTER							

Pressure Filter Charge, gms	68896.0	71142.0	61532.0	50782.0	49061.0	49181.0	48762.0
Pressure Filter Cake, gms	9877.0	9852.0	7218.0	2727.0	1743.0	665.0	709.0
Pressure Filter Liquid, gms	55768.0	57880.0	51059.0	45746.0	44265.0	45937.0	45156.0
Pressure Filter Loss, gms	3251.0	3410.0	3255.0	2309.0	3053.0	2579.0	2897.0
W% Pfs	14.34	13.85	11.73	5.37	3.55	1.35	1.45

Period Number	37T	38T	39T	40T	41T	42T	43T
----CHARGE, PRODUCT, AND RECYCLE RATES-----							
FEED RATES, GRAMS/HOUR							
Total Carbonaceous Feed	1813.8	1810.2	2259.8	2348.7	2253.2	2357.6	2410.5
Dry Carbonaceous Feed	1632.5	1647.3	2033.8	2113.8	2253.2	2121.9	2410.5
Total Makeup Oil Rate	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water to Hot Separator	417.1	413.2	415.5	379.3	414.5	408.6	412.9
H2 to 1st Stage	192.8	191.3	191.6	192.8	192.8	192.8	192.8
H2 to 2nd Stage	84.4	84.4	84.4	84.5	84.5	84.4	84.4
RECYCLE RATES TO REACTOR, GRAMS/HOUR							
PFL Recycled to Slurry + Pretreater Buffer	1884.8	1778.6	677.9	327.7	314.7	329.3	336.7
CAS Bottoms Recycled	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pfl to 1st Stage Buffer	45.1	59.7	44.5	45.6	140.1	38.0	39.0
Pfl to 2nd Stage Buffer	34.9	38.7	62.2	39.9	68.6	37.5	36.9
NET COLLECTED PRODUCTS (INCLUDING SAMPLES), GRAMS/HOUR							
Total Gas (incl. N2)	663.0	624.2	636.1	611.7	635.3	679.5	681.5
(N2 free)	550.4	502.1	520.1	500.1	515.3	569.7	576.9
SOH	557.4	509.5	442.1	460.0	490.8	530.1	557.9
SOH-H2O	617.0	522.4	528.8	451.6	453.0	443.0	444.1
SOH-NET WATER	199.9	109.2	113.3	72.3	38.5	34.4	31.2
Knockouts	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Filter Cake	411.5	410.5	300.8	113.6	72.6	27.7	29.5
Filter Liquid	494.3	676.8	1478.5	1589.0	1448.2	1616.8	1589.7
Asoh + KO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total CAS Bottoms	2881.9	2986.3	2581.5	2154.1	2069.7	2067.8	1988.2
Reactor 1 Liquid Sample	0.0	14.6	2.9	2.5	14.3	4.1	17.5
Separator Bottoms to CAS	2881.9	2986.3	2581.5	2154.1	2069.7	2067.8	1988.2
Total Asoh	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAS Bottoms to Pressure Filter	2870.7	2964.3	2563.8	2115.9	2044.2	2049.2	2031.8
Total Filter Cake	411.5	410.5	300.8	113.6	72.6	27.7	29.5
Total Filter Liquid	2459.1	2553.8	2263.1	2002.3	1971.6	2021.5	2002.2

'iod number	37T	38T	39T	40T	41T	42T	43T
--NET ADJ. PRODUCTS, W% DRY Total Feed -----							
Total CO + CO2	3.37	3.05	1.02	0.21	0.09	0.10	0.06
Total C1-C3	6.94	5.87	4.56	4.22	3.70	4.84	4.39
Total C4-C7	2.80	2.29	2.05	2.43	2.25	2.89	2.87
SOH TOTAL H2O	37.80	31.71	26.00	21.36	20.10	20.88	18.42
SOH NET WATER	12.25	6.63	5.57	3.42	1.71	1.62	1.29
SOH Distillate Oil	34.14	30.93	21.74	21.76	21.78	24.98	23.14
Asoh + KO	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pfl	30.87	42.24	73.47	76.88	65.36	77.06	64.17
Pfs	25.31	25.11	14.89	5.47	3.26	1.32	1.20
CAS Bottoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reactor 1 Liquid Sample	0.00	0.89	0.14	0.12	0.63	0.19	0.72
H2 Consumed--Meter, W% Dry Feed	6.6	6.4	4.7	3.8	2.9	3.1	3.2

PERIOD NUMBER GAS YIELDS (Overheads), W% of mf coal	37	38	39	40	41	42	43
CH4	1.40	1.29	1.03	0.87	0.83	0.89	0.70
C2H4	0.05	0.05	0.04	0.06	0.04	0.05	0.04
C2H6	1.23	0.95	0.75	0.73	0.59	0.77	0.67
C3H6	0.19	0.13	0.13	0.22	0.18	0.23	0.23
C3H8	1.57	0.98	0.82	0.95	0.70	1.00	0.99
C4H8	0.17	0.13	0.13	0.25	0.20	0.33	0.33
N-C4H10	0.67	0.42	0.35	0.48	0.36	0.54	0.60
I-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.32	0.23	0.25	0.40	0.28	0.39	0.35
I-C5H12	0.16	0.13	0.14	0.23	0.20	0.33	0.27
METHYL-CYCLOPENTANE	0.00	0.00	0.00	0.03	0.00	0.04	0.00
CYCLOHEXANE	0.04	0.11	0.06	0.00	0.00	0.00	0.03
N-C6H14	0.08	0.04	0.03	0.03	0.03	0.07	0.09
C6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.83	0.65	0.42	0.10	0.05	0.06	0.04
CO2	2.38	2.30	0.55	0.10	0.03	0.04	0.02
H2S	4.08	2.63	3.26	2.28	1.86	2.80	2.81

PERIOD NUMBER GAS YIELDS (Bottoms), W% of mf coal	37	38	39	40	41	42	43
CH4	0.90	0.95	0.61	0.47	0.45	0.66	0.61
C2H4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H6	0.71	0.63	0.49	0.39	0.36	0.54	0.51
C3H6	0.01	0.01	0.00	0.01	0.01	0.00	0.01
C3H8	0.89	0.87	0.70	0.54	0.54	0.71	0.63
C4H8	0.00	0.00	0.00	0.00	0.01	0.00	0.00
N-C4H10	0.54	0.54	0.41	0.36	0.38	0.46	0.43
-C4H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C5H10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N-C5H12	0.28	0.27	0.25	0.24	0.30	0.29	0.29
-C5H12	0.13	0.14	0.16	0.17	0.21	0.22	0.22
ETHYL-CYCLOPENTANE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
YCLOHEXANE	0.24	0.13	0.10	0.02	0.07	0.02	0.02
-C6H14	0.11	0.09	0.05	0.07	0.05	0.06	0.08
6-C7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O	0.05	0.04	0.02	0.00	0.00	0.00	0.00
O2	0.10	0.07	0.03	0.01	0.00	0.00	0.01
2S	4.35	4.50	4.37	3.87	4.31	4.87	4.33

DETAILED GAS NORMALIZED YIELDS

PERIOD NUMBER	3	7	10	14	18
PERIOD START	11/30/95	12/04/95	12/07/95	12/11/95	12/15/95
ORMALIZED YIELDS, W% DRY FRESH FEED					
C1	2.74	3.68	3.72	3.20	2.15
C2	2.46	2.89	3.60	3.46	1.76
C3	3.19	3.53	4.93	4.40	2.10
C4	1.89	2.03	3.00	2.24	1.18
C5	1.11	1.43	1.47	1.05	0.89
C6-C7	0.47	0.59	0.88	4.73	0.74
ORMALIZED YIELDS, W% MAF BASIS					
C1-C3	8.91	10.71	13.00	11.72	6.19
C4-C7	3.67	4.30	5.67	8.51	2.89

DETAILED GAS NORMALIZED YIELDS

ERIOD NUMBER	22	26	30	34	38	43
ERIOD START	12/19/95	12/23/95	12/27/95	12/31/95	01/04/96	01/09/96
RMALIZED YIELDS, W% DRY FRESH FEED						
C1	1.47	1.48	1.55	2.21	2.10	1.33
C2	1.30	1.23	1.35	1.86	1.53	1.24
C3	1.65	1.12	1.87	2.21	1.87	1.90
C4	1.19	1.08	1.27	1.31	1.01	1.38
C5	1.14	1.05	1.21	1.00	0.72	1.15
C6-C7	0.27	0.27	0.54	0.56	0.42	0.39
RMALIZED YIELDS, W% MAF BASIS						
C1-C3	4.45	3.87	4.81	6.47	5.80	4.51
C4-C7	2.62	2.42	3.05	2.95	2.27	2.95